

PB-217 671

STUDIES ON HOUSEHOLD SEWAGE DISPOSAL
SYSTEMS. PART I

S. R. Weibel, et al

Environmental Health Center
Cincinnati, Ohio

1949

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Studies On Household Sewage Disposal Systems

First in a series of research reports on
individual sewage disposal systems

by

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PART I

- A. Review of Literature
- B. Controls & Practices in Local Health Units
- C. Experimental Study--Septic Tanks
- D. Field Study--Sludge & Scum Accumulation
- E. Sludge, Yeast, as Starters
- F. Zeolite Softener Salts & Digestion
- G. Freezing Aspects

FEDERAL SECURITY AGENCY
Public Health Service
Environmental Health Center
Cincinnati, Ohio

1949

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STATEMENT OF THE JOINT COMMITTEE ON RURAL SANITATION ON THE RESEARCH REPORT

The Joint Committee recognizes the value and importance of the research studies set forth in the first research report on the Household Sewage Disposal Project conducted by the Public Health Service and sponsored by the Housing and Home Finance Agency at the Environmental Health Center at Cincinnati, Ohio. The Committee wishes to point out that the work reported thus far has been confined to the septic tank and therefore is not applicable to the entire Individual Sewage Disposal System.

It is the opinion of the Joint Committee that with this additional information, it is now possible to modify the present "Recommendations of the Joint Committee on Rural Sanitation," entitled, "Individual Sewage Disposal Systems," which are contained in Reprint No. 2461 of the *Public Health Reports* as follows:

- (1) To permit variations in shape within reasonable limits, provided, that the total liquid capacity is not reduced below 500 gallons.
- (2) Insofar as suspended solids reduction is concerned, multi-compartment tanks also appear to be satisfactory, however, when used, the total liquid capacity should not be less than that set forth in tables 1 and 2 of the existing recommendations; no single compartment should contain less than 125 gallons; and the inlet and outlet connections and baffles for each compartment should follow the principles set forth for inlet and outlet connections and baffles in single compartment tanks, provided such connections or baffles do not extend below the mid-depth of the liquid.
- (3) Consideration should be given location of individual compartments and their relation to each other to permit convenient access to all compartments thus assuring complete servicing of the entire tank installation.
- (4) Only durable materials should be used in the tank construction if the costs of maintenance and replacement are to be considered in the economic evaluation of the individual sewage disposal system to the property owner.

The need for education of the public through activities of local health authorities for periodic inspection and cleaning of septic tanks is apparent.

MARCH, 1949

FOREWORD

The significance of the household sewage disposal system in the field of sewage disposal in this country is amply reflected in the 17 million persons estimated as served by residential septic tank--soil absorption systems. With trends toward living in suburban fringe and rural non-farm areas, beyond reach of community sewer systems, the continued utilization of some type of individual residential sewage disposal is indicated.

Difficulties with the operation of such systems, and attempts on the part of governmental agencies to find and utilize the best available information in this field, have brought out the lack of a basic factual foundation. In order to establish the factual foundation necessary for effective design concepts for the use of governmental agencies as well as others concerned, the Housing and Home Finance Agency and the Public Health Service initiated a broad program of study of this problem, beginning the work in early 1947.

This report, the first of a series, Studies on Household Sewage Disposal Systems, presents the findings on several of the individual topics undertaken to date under this program. Additional reports in the series will be prepared from time to time as the work progresses.

In that the final significance of results on some of the individual elements, in relation to the system as a whole, cannot be determined until the facts on related elements, either now under study or to be undertaken later on, are known; caution should be exercised in the application of the piecemeal findings.

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INTRODUCTION

Authorization

The Project was inaugurated in November, 1946, through arrangement by conference and exchange of correspondence between representatives of the National Housing Agency, the Office of the Housing Expediter and the Public Health Service, and the assignment of a working fund by the National Housing Agency to the Public Health Service for the conduct of the Project.

Objectives

A list of topic objectives, developed through joint conferences between staff members of the Technical Service Branch, National Housing Agency (now the Housing and Home Finance Agency) and the Public Health Service, is presented below. It was agreed that specific needs of the housing program at various times may require that increased emphasis be placed on special testing and investigation work in connection with particular items on the list, but in general a work program would be followed and the facilities of the Public Health Service used in such a manner as to provide the maximum of data on as broad a scope as possible in the shortest possible time. The list of projects is as follows:

1. Collection and analysis of existing data:
 - A. Review existing publications and unpublished studies both domestic and foreign, regulations, and commercial brochures on the design, capacity, durability of construction materials and operating results of septic tanks and disposal systems and indicate such publications that offer information on acceptable principles to be followed.
 - B. Select representative installations of various types for testing and gauging operations.
2. Investigate existing installations of different sizes, shapes, types, and materials, and determine efficiency of sedimentations, durability of materials, adequacy of sludge storage, and other basic characteristics.
3. Conduct such short term testing and research as may be possible and desirable to substantiate such items as efficiency of sedimentation, adequacy of sludge storage, capacity, size, shape, durability of materials and other comparable characteristics of commercial septic tanks.
4. Locate, construct, or otherwise secure at properly selected field locations and operate, under normal conditions, tanks of some flexibility for trials and pilot studies.
5. Locate, construct, or otherwise secure at properly selected field locations and operate subsurface systems on experimental basis, including experimental seepage test holes, trenches, tile lines, and complete subsurface installations.
6. Initiate sampling, gauging, and testing of several installations representative of current practices.

7. Conduct laboratory investigations on the soil-clogging characteristics of tank effluent.
8. Study the economic and general feasibility of constructing systems with sufficient sludge capacities to require cleaning at only 10 or 20-year intervals.
9. Study the effect of extreme freezing conditions on the functioning of a properly designed and constructed subsurface disposal field and determine what modifications should be incorporated in accepted design practices for cold climates.
10. Study the effect of tree and shrubbery roots on disposal systems and the ability of roots to absorb significant portions of sewage effluent through all seasons of the year.
11. Determine the effect of residential garbage grinding on septic tank operation and what modifications in design should be made to permit this service.
12. Test various distribution box installations as a basis for determining the most efficient design for these structures.
13. Investigate feasibility of changing the ratio of horizontal and vertical areas of septic tanks so as to permit a shorter detention period and increased sludge storage capacity.
14. Study the discharge of normal amounts of grease directly into a septic tank of adequate size and determine the effect of grease on septic action and on the efficiency of septic tank systems.
15. Determine the relation of Sodium and Calcium to the soil-clogging action of the effluent.
16. Investigate the relationship of (a) seepage, lateral or vertical (b) evaporation and (c) transpiration of the overall efficiency of a subsurface disposal system.
17. Study and investigate new methods of disposal, particularly substitute methods for subsurface disposal.
18. Develop recommended minimum standards of design for septic tank systems.

Start of Work

In order to get an early start on the Project pending the recruitment of temporary personnel for the work, members of the Environmental Health Center staff were made available to carry out various preparatory assignments, enabling the review of literature to be started in December, 1946, the assignment of field engineers as soon as recruited in February, 1947, to areas selected as a result of previous investigation by engineers of the Health Center, and providing for a laboratory, experimental equipment and training of scientific personnel enabling the start of the experimental tank work in June, 1947.

Informal Advisory Committee

An informal advisory committee, composed of representatives of the several agencies, as listed below, has met at the Environmental Health Center at Cincinnati from time to time during the course of the work to discuss progress and advise on various problems arising in

connection with the work. At its last meeting in May, 1948, the Committee considered the progress of several parts of the work as sufficiently advanced to prepare a report upon completion of a series of runs on the experimental tanks at the end of June, 1948, as a consequence of which the preliminary report herein has been prepared.

The informal Advisory Committee has included the following at various times during its several meetings:

Housing and Home Finance Agency - Messrs. L. Shuman, F. McGhan, E. Hopkins, Professors

E. Boyce and R. King, University of Michigan

Federal Housing Administration.--Mr. J. R. Simpson

Public Housing Administration.--Messrs. R. Van Derwerker, K. Lauster

Joint Committee.--Mr. C. A. Betts, Forest Service, U.S.D.A.

Public Health Service.--Messrs. L. M. Fisher, H. W. Streeter, V. G. MacKenzie

Valuable guidance and insight to the practical problems in the field was furnished by the Committee during these meetings, for which grateful acknowledgement is made.

Progress Reports

Monthly reports on the Project starting with January, 1947, were prepared for the information of the sponsoring Agency, the Advisory Committee and the Joint Committee on Rural Sanitation. Two progress reports outlining the progress of the work in some detail were prepared for the Agency and Committees above mentioned, the first in August, 1947, and the second in January, 1948.

This Report

The several parts of the work considered sufficiently advanced to include in a preliminary report at this time are included under the seven sections listed below. These are offered as preliminary reports, subject to modification, and supplementation as additional information is developed through further examination of the data at hand and from work yet to be done.

Because of the complexity of problems involved and the very limited information available on basic factors in this field, much experimental work, fortified by verification in the field, will be required before the design and operation of household soil absorption sewage disposal systems can be placed on a factual foundation.

In the meantime, considerable benefit may be derived from trends developing experimentally or from field observation, however limited they may be, provided the limitations are kept in mind, and this report is released with this in mind. It is intended that the work reported herein, together with other work which may be similarly reported from time to time, will eventually be integrated into a comprehensive report on the household sewage disposal system.

The seven sections reported herein are as follows:

- A. Review of Literature
- B. Survey of Controls and Practices in Some Local Health Units
- C. Study of Experimentally Operated Septic Tanks
- D. Study of Septic Tanks in Field--Sludge and Scum Accumulations
- E. Laboratory Investigation of Sludge, Yeast, as Starters of Digestion
- F. Experimental Investigation of Effect of Zeolite Softener Salts on Digestion
- G. Survey of Information on the Freezing Aspects of Household Sewage Disposal systems

Other Work Undertaken

Other undertakings thus far in connection with the Project are listed below. Preliminary reports on these or other work undertaken may be released from time to time as the work progresses. Work on these has been suspended at the present time:

- I. Sampling and gauging of household septic tanks in normal operation - four such systems have been covered.
- II. Preliminary laboratory investigation of clogging behavior of some septic tank effluent bacteria applied to sand columns, and clogging of sand columns by effluents from various experimental septic tanks.
- III. Experimental investigation of addition of ground garbage to a septic tank.
- IV. Installation and dosing of six 50 foot experimental tile lines installed under various circumstances of cover, grade and trench width for future observation.
- V. Experimental investigation of the joint distribution characteristics of farm tile under various grades and dosing circumstances.
- VI. Percolation test experiments together with mechanical analysis of soils.

Acknowledgments

Grateful acknowledgment is made of the assistance given the Project by representatives of the Housing and Home Finance Agency, Federal Housing Administration and Public Housing Administration, the Public Health Service Sanitary Engineering Division, and the Environmental Health Center in guidance given at the several conferences and various aids in particulars too numerous to outline; the Public Health Service District Offices for liaison in connection with the opening of field study areas, for providing desk space, transportation and assistance in hiring field labor; the State, County and Municipal Health Departments cooperating in the areas in which study has been or is now being made and those also who offered similar cooperation in their respective areas; the manufacturers of tanks, appurtenances and equipment who made special efforts to expedite delivery of purchases for the Project; the universities, engineering schools, agricultural colleges, extension and experiment stations, libraries, individual scientists in the United States and foreign countries, and manufacturers who willingly responded to requests in connection with the review of literature; and finally, the staff of the Project, which has undertaken assignments, some of which are far from pleasant, with willingness and purpose seldom obtained in a necessarily hastily organized temporary staff.

Personnel

The Project is operated as one of the activities of the Environmental Health Center at Cincinnati under the administrative direction of Sanitary Engineer Director H. W. Streeter, Officer in Charge, succeeded upon retirement in June, 1948, by Sanitary Engineer Director V. G. MacKenzie, Officer in Charge.

The authors were assisted by Chemist Jesse Cohen, Engineer F. E. Longan, and Messrs. E. Fosher and H. Ray in the preparation of material for this report.

The staff of the Project included the following engineering, scientific and clerical personnel employed at one time or another for varying periods of employment; a considerable turnover in personnel was experienced because of the temporary status of the job:

<u>Name</u>	<u>Title and Grade</u>	<u>Assignment</u>
	<u>Engineering</u>	
Weibel, S. R.	S. A. San. Engr.	In Charge of Project
*Straub, C. P.	San. Engr.	Conduct research program

<u>Name</u>	<u>Title and Grade</u>	<u>Assignment</u>
<u>Engineering--Cont.</u>		
*Thoman, J. R.	S. A. San. Engr.	Central office, review lit., analysis
Solander, A. A.	P. H. Engr.	Research, Cincinnati
Retter, H. H.	S. A. Engr. (R)	Field survey
Agnano, P.	S. A. San. Engr. (R)	Field survey
Shipp, J. W.	S. A. San. (R)	Field survey
Hamblett, W.	P. H. Engr.	Research, Cincinnati
Longan, F. E.	P. H. Engr.	Field survey
Edwards, C. H.	Eng. Aide	Field survey
*On loan from Cincinnati Station staff		

<u>Scientific</u>		
Clark, H. F.	Chemist	Research, Cincinnati
Cohen, J.	Chemist	Research, Cincinnati
Tubiash, H. S.	Bacteriologist	Research, Cincinnati
Griffiths, W. S.	Chemist	Research, Cincinnati

<u>Clerical</u>		
Guethlein, M. L.	Clerk Steno.	Central Office, Cincinnati
Droege, F.	Clerk Steno.	Central Office, Cincinnati
X Foshier, E. C.	Clerk Steno.	Central Office, Cincinnati

There were in addition to the above a number of scientific aides and laborers recruited for short periods of time, many of them students employed during the summer of 1947.

As of the completion of this report the personnel assigned to the Project consists of an engineer, clerk-stenographer and laborer.

Number of Septic Tanks in the United States

No accurate estimate of the total number of septic tanks in the United States exists, nor do any data exist which will furnish this information in a straightforward manner. The methods which have been used in preparing this present estimate, are based on the use of data which in itself is an estimate, and should be reviewed in that light. However, no other method of obtaining any reliable figure was found.

According to this method of estimation there are approximately 4,400,000 septic tanks in the United States. The 1944 National Inventory of Sanitation Needs was used for supplying the necessary data, and all information is from this report.

I. Population for which extensions to existing sewer system are needed:

10,297,300 - approx. 2,574,300 dwellings

II. Population for which new sewer systems are needed:

4,835,847 - approx. 1,208,900 dwellings

III. Rural dwelling units in U. S. 12,971,360

Outside toilet or privy 8,505,572

No toilet or privy 846,148

9,351,720

9,351,720

Units with some other disposal 3,619,640

1. Assume 80% of units in Class I	2,000,000
2. Assume 50% of units in Class II	600,000
3. Assume 50% of units in Class III	<u>1,800,000</u>
	4,400,000

Class I includes the population in incorporated communities of over 200 pop. which need extensions to sewer systems. According to the 1944 Inventory only those actually needing extensions are reported. It may be assumed that a large percentage of the homes in these areas are equipped with running water and flush toilets, since sewers need only extension, and hence in planning for such future work would probably be equipped with septic tanks or some type of water-carriage sewer disposal.

Class II includes the population in incorporated communities of over 200 pop. for which new sewer systems are needed. In this case it might be expected that privies are in widespread use, hence it was assumed that only 50% of the homes in this category are equipped with septic tanks.

Class III includes rural homes from a different standpoint than that usually employed by the Census Bureau. It includes all homes in the Rural-Farm classification, and those Rural-Nonfarm homes outside of incorporated communities. The total figure includes dwellings equipped with septic tanks or other disposal methods (to storm drains, ditches, cesspools, etc.), and also those units having non-flush toilets in the house. This latter item is probably less than 1% of the total units involved, and has not been considered. Since the dwellings equipped with privies are not included in this figure, it seems reasonable to assume that 50% of the units in this class are equipped with septic tanks.

On the basis of the above, the population served by the 4,400,000 septic tanks would amount to about 17,000,000 persons. The significance of the size of this field of sewage disposal may be more clearly appreciated when it is compared to that of municipal sewage treatment in the United States which totals about 42 million persons served, on the basis of 1942 figures. Secondary treatment in the municipal field, a degree of treatment approaching that provided by a septic tank soil absorption system, represents 20 million persons. Considering further that the two popular secondary municipal processes, activated sludge and trickling filters, which have received considerable attention in the development of factual information in past years, represent only 11 million and 8 million persons served respectively, it is apparent that the development of a factual foundation for sewage disposal in a field representing 17 million persons is well justified, and long overdue.

SUMMARY

A. Review of Literature

1. A check of over 600 references was made to develop information on past research and on design practices throughout the world.

2. References to factual study were few, and those limited in scope. The literature survey did not disclose any work on other than rectangular shaped tanks.

3. A few factual studies are under way at the present time, concerning both tanks and soil absorption, notably the study at the University of Michigan on tanks, which includes an investigation into tank behavior without freeboard, and the study at Rensselaer Polytechnic Institute, devoted to soil absorption characteristics.

4. There appears to be no common denominator of design throughout the world. The nearest approach to uniformity appears in the recommendations of the various States in the United States, although there are wide variations in some cases. A minimum liquid capacity of 500 gallons is recommended in 72 per cent of the States.

5. The percolation test rests on a very limited factual background. Practically no factual information on soil clogging was found.

6. The field as a whole appears to be suffering from an abundance of concepts which have gained credence through repetition of opinion. Some or many of these may be valid, but factual data have yet to be developed to test them out.

B. Survey of Controls and Practices in Some Local Health Units

1. A field of 1247 U.S. city, county and combination health units having full time health officers was circularized by questionnaire with a total response from 794, or 64 per cent of the field. This included replies ranging from acknowledgement of questionnaire with indication of no control; or no available information, to the fully executed questionnaire.

2. About 80 per cent of the 726 units, which furnished at least some information on the question of control, indicated control of some sort, lodged in the health department in practically all cases.

3. Of 444 units providing date control started, one-quarter started control before 1935 and the remainder since that time.

4. A review of ordinance material reveals a variety of items of much interest and apparent usefulness for those who wish to improve local control.

5. About 40 per cent of present installations were installed under control in areas for which installation figures were given.

6. Approximately half the units require installation permits; one fourth, installation by skilled tradesmen. Over 60 per cent keep records of installations and complaints.

7. Weakness is shown in failure to inform householders of servicing responsibilities. Preliminary examination of installation circumstances also appears weak. However, the numbers reporting control of individual absorption system size and final inspection before back-filling appeared encouraging. With improvement in technology the latter should be effective.

8. The number of complaints ranged from 0 to 25, or more, per month for individual health units in 18 States; from 0 to less than 25 per month per unit in the remaining States.

9. The most frequent complaint is seepage to ground surface, followed in frequency by odor nuisance, plumbing stoppages, sewage backing into cellar, and a miscellany of other items. Causes of difficulty were most frequently clogged tile fields, tank cleaning overdue, sewer clogged, tank inlet clogged, and miscellaneous other difficulties (Cleaners say that tank cleaning is overdue in over 50 per cent of calls).

10. Regulation of cleaning services was in effect in only one fourth of the units. Difficulties with cleaning services were indicated by 68 per cent of the units.

11. Successful local measures reported included application of State health department recommendations, plumbing and building codes and permits, local control and design, proper installation, ordinances, proper tank, publicity, etc.

C. Study of Experimentally Operated Septic Tanks

1. Eighteen full sized septic tanks representing a variety of shapes and sizes were compared, under parallel operating conditions, on the basis of solids removal for periods up to a year. The eighteen tanks are identified as follows:

Tank No.	Description	Total Liquid Cap. (Gallons)	Tank No.	Description	Total Liquid Cap. (Gallons)
1	Jt. Comm., Rect.	2,060	10	Jt. Comm. Rect. (Tee outlet)	539
2	Round End	513	11	Jt. Comm. Rect. (Weir outlet)	539
3	2-36" Dia. Vert. cyl. in Series	553	12	24" Dia. Vert. Cyl.	123
4	4-24" Dia. Vert. cyl. in Series	673	13	2-24" Dia. Vert. Cyl. in Series	246
5	Oval	525	14	24" Dia. Hor. Cyl. (3 Comp.)	289
6	52" Dia. Vert. Cyl.	455	15	Jt. Comm. Rect.	539
7	Jt. Comm. Rect.	539	16	2 Comp. Rect.	539
8	52" Dia. Hor. Cyl.	492	17	3 Comp. Rect.	539
9	Jt. Comm. Rect. (Garbage and Sew.)	539	18	Rect. -3' Depth	405

2. The tanks were dosed 8 times a day from 7 AM to 10:30 PM from a central feed tank. Combined sewage from a residential section of Cincinnati was used. Following seeding of the

tanks, an initial run was made at 500 g.p.d. (most tanks were about 500 gal. capacity), after which the dosage was reduced to 250 gal. per day. Sludge accumulation was accelerated by adding sludge obtained from septic tank cleaners. Samples composited from all doses were examined routinely for solids, occasionally for B.O.D., sulfides, grease, ammonia and chlorides.

3. An initial run was made with 8 tanks at a dosage of 500 gallons per day each, after seeding, during which the efficiencies of suspended solids removal ranged from 16 to 60 per cent for the various tanks, tanks No. 1, 3 and 4 having the highest efficiencies, 60, 59 and 56 per cent respectively. The subsequent reduction of dosage to 250 gallons per day resulted in higher efficiencies for all tanks and narrowed the spread in efficiencies, the range being 53 to 76 per cent. Following this run, four successive runs were made, each preceded by the addition of quantities of sludge to each of the tanks, to enable the determination of efficiencies over a range of sludge accumulations equivalent to from 1 to over 9 years service.

4. Other tanks were added to the original 8 at various times during the year's study, some of which received a short period of operation up to the time of suspension of the Project in June, 1948. Further operation of these is intended when the Project becomes active again.

5. Comparison of tank shapes and sizes on the basis of suspended solids reduction revealed considerable difference in the operating efficiencies of the tanks. Tank 4 showed highest efficiency. At relatively the same order of efficiency were tanks 1 and 3. The 5 single compartment tanks in the 500 gallon size gave overall efficiencies of about the same magnitude during their useful period although there were differences in the individual runs, and considerable difference in normal operating life (point at which sludge discharges) indicated by the sludge accumulations. Circular shapes in series, in effect, compartmentation, consistently provided a higher degree of suspended solids reduction than any of the single compartment tanks of about the same capacity.

6. Three runs on a 24 inch diameter vertical cylindrical tank of 123 gallons capacity; two such tanks in series, totaling 246 gallons capacity; and a 24 in. diameter horizontal cylindrical, 3 compartment tank of 289 gallons capacity, indicated a fairly high percentage removal of suspended solids, and particularly so considering that they were dosed at 250 gallons per day. However, their normal operating life appeared to be very short as compared to the 500 gallon tanks.

7. A single run on a battery of 4 rectangular tanks of single, double and triple compartments, and a shallow single compartment rectangular tank, was beset with leakage troubles and the results, though shown, are not considered too significant. Additional investigation is intended.

8. Apparent improvement in solids reduction efficiency as sludge accumulations increase to some point, indicates the desirability of investigating the introduction of influent through the sludge.

9. Grease removals of 71 to 92 per cent were obtained during the experimental runs. the raw sewage grease concentration was about 190 p.p.m., which is fairly representative of municipal sewage.

10. Experimental comparison of a standard Tee outlet with a baffled weir outlet on a 500 gallon Joint Committee type tank revealed no significant difference in effluent quality.

11. Tables of estimated years of tank operation based upon sludge, and sludge plus scum accumulations, indicate considerable difference in the solids retaining capacities of the various tanks.

D. Study of Septic Tanks in Field, Sludge and Scum Accumulations

1. A total of 300 household septic tank systems were inspected in 9 geographical areas over the country.

2. Statistics on household characteristics indicated that for 296 of these households the number of bedrooms per dwelling was 2.49, and the number of persons per bedroom averaged 1.5. Metered water usage at 170 of the group averaged 49 gallons per capita daily in the summer as against 39 during the winter.

3. Examination of data on the condition of structural materials in 244 concrete, concrete block, vitrified tile, brick and steel septic tanks revealed that corrosion was most severe at and above the water line. In general, pre-cast concrete, tile and brick stood up well for 20 years or more; poured-in-place concrete, for at least 10 years (no data for older tanks); steel tanks averaged a 7 year useful life, running as high as 12 years in individual cases in the group of tanks examined. Wood baffles were found sound in tanks up to 7 years old.

4. For 205 tanks considered, the average sludge and scum accumulation rates for the group tended to be upwards of 3.4 cubic feet per capita per year during the first year, dropping down, presumably because of digestion and compaction, to 1.34 cubic feet per capita per year at the 6 or 7 year mark and continuing on at that rate. On this basis, twice the one year effective sludge and scum storage capacity would appear to extend the interval between cleanings to 4-1/2 years; three times, to 7 years.

5. Measurements of scum layers on 150 tanks indicate that about 27 per cent of the total thickness will lie above the water line.

6. Scum and sludge accumulations in 80 tanks receiving all wastes, average only 0.15 cubic feet per capita annually more (11 per cent) than the average accumulation rates for 62 tanks receiving bathroom wastes only.

7. Capacity appears to be a very important factor in the accumulation of solids. Per 205 tanks the average solids accumulation fell in the 125 to 175 gallons per capital group, with less solids accumulation in smaller tanks, more in larger tanks.

8. Solids accumulations appear to increase with depth, although the influence of capacity is not eliminated from this examination.

9. While solids accumulations appear also to increase with tank surface area, capacity again tends to mask the trend.

E. Laboratory Investigation of Sludge and Yeast, as Starters on Digestion

1. Pottle experiments indicate that a sewage volatile solids to ripe sludge volatile solids ratio of 1 to 4.4 will reduce the lag in start of digestion.

2. In that digestion proceeds slowly at lower temperatures it appears advantageous to seed tanks placed in operation in northern climates. Also, to avoid risking a period of malodorous operation until alkaline digestion is established, seeding appears advantageous.

3. On the basis of the sludge used in the experiments about 6 gallons of digested sludge per capita would be required as a starter. Additional investigation is needed to fortify this observation.

4. On the basis of bottle experiments the addition of yeast to sewage does not stimulate digestion for at least 25 days.

5. Addition of yeast to sewage-ripe sludge mixtures appeared to have a stimulating effect on gas production. This was believed due more to production of gas from the organic matter in the yeast suspension (yeast plus starch) than to stimulation of digestion in the sewage-sludge mixture. As indicated above, ripe sludge alone is adequate as a starter.

F. Experimental Investigation of Effect of Zeolite Softener Salts on Digestion

1. Bottle experiments tracing the course of digestion of sludge-sewage mixtures containing 0.6 and 1.2 per cent salt (NaCl , CaCl_2 and MgCl_2) concentrations respectively indicate a pronounced inhibiting effect with a 1.2 per cent salt concentration, and much less inhibiting effect with the lower concentration, during 180 hours contact. Further tests indicated that salt concentrations of 0.2 and 0.4 per cent have no detrimental effect on gasification.

2. It was further found that the effect of toxic concentrations is reduced by flashing (mixing and dilution). After 2 to 48 hours contact with 1.2 per cent salt concentrations, followed by dilution, recovery from initial lags develops within 150 to 200 hours.

3. A 2.4 per cent salt concentration in tanks No. 2 and 3 failed to dilute in the lower part of the tanks when dosed at the 250 gallon per day feed rate, although mixing and dilution did take place in the upper part of the tank. With instantaneous mixing, practically all of the salt should theoretically discharge from the tanks in a week. Actually only 50 per cent of it did.

4. The tests made thus far on two full sized tanks indicate that the mixing obtained in the tanks, through intermittent discharge of sewage through the tanks, was inadequate to reduce the salt concentration in the lower part of the tanks. It appears from this that salts could accumulate at the lower levels in the tank due to repetitive salt discharges until toxic levels are reached. Tests over a longer period, with simulated repetitive discharges of salts with the incoming sewage should be carried out in this connection.

5. In sub-toxic concentrations, salts appeared to stimulate digestion.

G. Survey of Information on the Freezing Aspects of Household Sewage Disposal Systems

1. From comments in the literature concerning freezing aspects in particular States or areas, and from a review of the recommendations of eleven northern States on small septic tank ground absorption systems, it appears that the freeze-up of a household system which has been installed with care, on the basis of the usual design recommendations of the States, is a rare occurrence. Only one of the colder border States recommends depths approaching the frost line, and one other recommends straw cover where subject to extreme frost.

2. From a review of several case histories it appears that difficulties are associated with failure to observe usual design recommendations, or to protect construction in freezing weather. Unprotected sewer lines under driveways appear to particularly weak points.

3. Investigation of tanks in some of the more northerly sections of Canada by the Ontario Agricultural College led to the conclusion that no trouble ensues from tanks 12 inches below ground and disposal tile 18 to 24 inches under ground, if kept in continual use, and if no part of the system is under a hard-packed roadway.

4. Investigation of recent country school system freeze-ups revealed unusual conditions, such as no heat added to the water and longer periods of idleness both daily and weekly, as compared with household systems. During the school freeze-ups there were no known reports of household freeze-ups.

5. A poll of northern plumbers indicated small incidence of freezing in shallow systems.

6. It appears from the data at hand that a carefully constructed shallow household system, with gravel packed tile lines, and insulation of pipes under driveways, or other surfaces usually cleared of snow, will rarely freeze if kept in continuous operation.

APPLICATION OF RESEARCH RESULTS

The work reported at this time represents but the start of a comprehensive investigation of the Household Sewage Disposal System. The present findings relate almost entirely to the septic tank itself, which is but one element of the problem. Some of the information obtained relates to other work either now in progress or to be undertaken at a later date.

The parts of the study reported herein are considered to have advanced sufficiently for release with proper qualification. However, piecemeal release of parts of the study in advance of the entire development, is not without risk, and caution should be exercised in applying the results of the work at this stage.

Conclusions regarding design, which the Public Health Services believes warranted, are as follows:

1. Data from 170 single family suburban type residences with metered water supply and served by septic tanks, showed mean per capita daily water consumption of 49 gallons in summer and 39 gallons in winter.

2. A household septic tank should function as:

- (a) A settling tank
- (b) A digesting tank
- (c) A sludge storage tank

3. On the basis of the usual assumption that suspended solids reduction is a satisfactory criterion of septic tank performance:

(a) There appears to be little difference in efficiency between uncompartmented tanks of rectangular, oval and circular shape of approximately the same capacity and depth. Variations in shape and depth within reasonable limits do not appear to affect efficiency greatly so long as tank capacity is adequate.

(b) Some type of compartmentation appears desirable. The study is not conclusive as to how this compartmentation shall be provided, the optimum shape, size, or number of compartments. Some means of cleaning each compartment of multiple compartment tanks should be provided.

(c) No unequivocal conclusion can be drawn from this report as to the minimum recommended design capacity for household septic tanks. Such tanks are seldom cleaned until trouble develops and it is important that capacity be ample to permit reasonably long periods of trouble free service and to prevent frequent and progressive damage to the effluent absorption system due to discharge of sludge by the tank. For these reasons it is believed that a capacity of at least 500 gallons should be provided.

4. Data on sludge and scum accumulations in 205 operating septic tanks of various sizes and shapes, serving single-family suburban type residences in various parts of the country, showed that during the first 5 or 6 years after the start of operation or cleaning, the average per capita accumulation of sludge and scum can be approximated by the following equation:

$$V = 17 + 7.5Y$$

where V = volume of sludge and scum in gallons per capita

Y = years of service since cleaning

This equation holds best for tanks of about 125 gallons per capita liquid capacity. Larger solids accumulations may be expected in larger tanks, smaller accumulations in smaller ones.

5. A limited study of 500-gallon rectangular tanks showed no significant difference in performance between a standard tee outlet and a baffled weir outlet.

6. The addition of yeast does not appear to accelerate sludge digestion in the tank. Seeding with digested sludge appears to be advantageous, however.

7. It appears from the data at hand that a carefully constructed household septic tank system with gravel-packed tile lines and insulation of pipes under driveways or other surfaces usually cleared of snow, will rarely freeze if kept in continuous operation even though the lines are above the level of frost penetration.

8. Corrosive action in the septic tank appears to be most severe at and above the water line. Concrete, particularly pre-cast concrete, vitrified tile and brick construction materials appear to stand up well in household septic tanks. Steel on the other hand appears to have a relatively short useful life expectancy. As this is chiefly a matter of protection of the steel, the need for development of an effective coating is indicated.

SECTION A

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Approximately 600 references to articles in periodicals, pamphlets, and books relating to septic tank sewage disposal systems were checked for information. This search of the literature was made primarily to develop information concerning past research projects and general design practices in countries throughout the world. References to research projects were few in number, and the studies described left much to be desired, doubtless due to the expense involved in conducting a thorough research program. Most references treated of design and construction practices, and in practically all cases were based on the author's opinions or experience with a group of installations. In many cases, design data were borrowed from another publication and together with minor changes and embellishments published as representing correct practice.

Most of the references were obtained by a systematic search of appropriate indices and some were located by solicitation of American colleges and universities. The following is a list of the material reviewed:

- A. *Engineering Index*, 1884 to 1945
- B. *Agricultural Index*, 1916 to 1945
- C. *Industrial Arts Index*, 1920 to 1945
- D. *Summary of Current Literature*, vol. 3 to vol. 16
- E. *Quarterly Cumulative Index Medicus*, vol. 27 to vol. 38

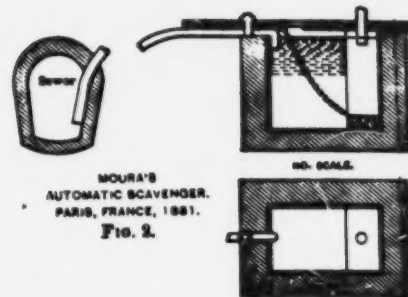
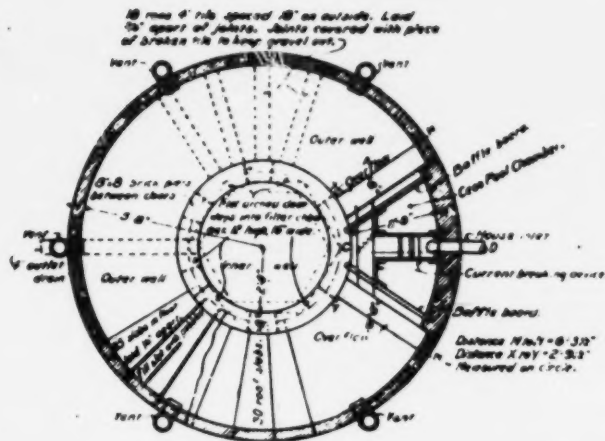
The survey of E. (above) was discontinued after checking these few volumes, as this index produced only two references. In addition to these sources, references were obtained from bibliographies accompanying some of the articles.

All information concerning an article was noted on a small file card, and in those cases where an abstract was available, this, too, was added. These cards were then sorted by years, and a rough appraisal made of the value of each article. Most articles considered to be worthwhile were then procured either in photostat or microfilm copies. The location of any particular volume of a journal was determined by referring to the *Union List of Serials* published by H. W. Wilson & Co. This volume lists all periodicals and the volumes, whether complete or not, which are obtainable in libraries in the United States. Articles from foreign journals were translated by Engineers C. P. Straub and H. H. Retter of the staff of this Project.

In the sections following, a review is made of the various factors employed in the design of septic tank systems, followed by rather detailed summary of the source material. The complete bibliography developed appears in Appendix A, accompanied by an author index.

The discovery of the household septic tank is generally credited to John Louis Mouras, who during the 1860's constructed a masonry tank in which sewage, kitchen wastes, and rain water from a small dwelling located in Vesoul, France, were collected before passing to a cesspool. Twelve years later the tank was opened, and found, contrary to expectations, to be almost free of solids. As a result a series of experiments were made in collaboration with a priest, Abbe Moigno, editor of *Cosmos les Mondes* and a scientific authority of his time. The satisfactory completion of these experiments induced Mouras to patent his invention on September 2, 1881. The Mouras tank is shown on Plate 1.

The experiments conducted by Mouras and Moigno consisted of the operation of a small, sealed tank with glass sides for observation of the phenomena occurring within the tank. Urine, fecal matter, and a small amount of water were added daily in one experiment, and Moigno stated that "introduced the 29th of August, the solid excretions were completely liquified by the 16th of September with the exception of materials not digested by the stomach ...". A sample of the tank effluent showed little turbidity and when diluted 1:10 with water had only a slight odor. The movement of particles within the tank from top to bottom, and conversely, was described, and an attempt made to determine if gas was generated by the



First septic tank
(from: Trans. ASCE, 1901)

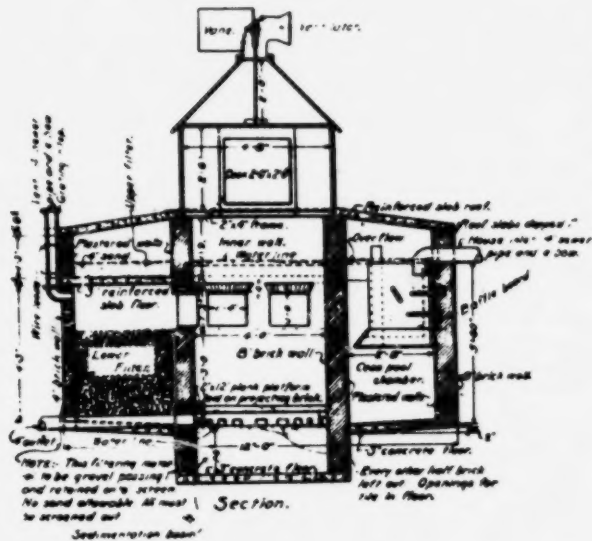
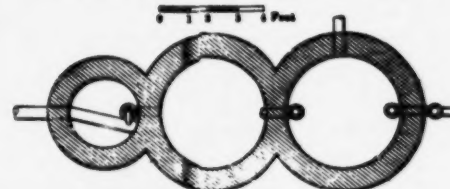
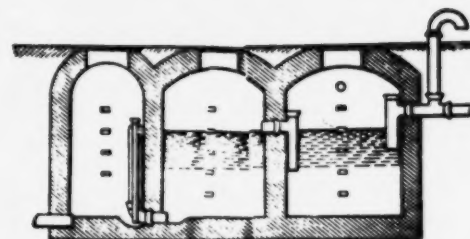


Fig. 1—Plan of Sewage Disposal Plant for Residences.

Tank designed by Marston at Iowa State
College in 1909
(from: Eng.-Com., 35:6:163 (2/8/11))



EDWARD S. PHILBRICK, BOSTON, MASS., 1923

One of first household septic tanks in the U. S.
(from: Trans., ASCE, 1901)

process. Moigno claimed that no gasses were given off when the tank was hermetically sealed, but that when air was permitted to enter the tank "...malodorous gas bubbles began to form, and increased with time". Finally, he concluded that liquefaction of the suspended material appeared more active when more water was used for flushing.

In the United States, it appears that the use of the household septic tank dates back to about 1883, when a two chamber, round, vertical tank, equipped with a dosing siphon for discharge of the effluent was designed by Edward S. Philbrick of Boston, Mass. The tank is shown on Plate 1.

The septic tank as a distinct process of sewage treatment was introduced in England by Cameron in 1895. Patents were obtained by Cameron both in England and the United States, and litigation resulting from alleged infringements developed in this country. A complete review of the situation was made by Leonard Metcalf in the 1901 *Transactions* of the American Society of Civil Engineers. Metcalf concluded that the individual functions inherent in the septic process were developed and used long before the process was patented by Cameron.

Sewage as received by a septic tank sewage disposal system will, in general, be somewhat different in character than that received in a sewage treatment plant. Due to the proximity of the tank to the dwelling unit the sewage will be very fresh, and will consist of the wastes from the various plumbing fixtures in the house. The sewage will include water closet and urinal wastes, lavatory and bath tub discharges, laundry wastes and kitchen wastes. In those houses equipped with a garbage grinder and/or a zeolite water softener, the wastes include ground garbage and/or regeneration wastes from the softener.

The character of the sewage from each household will differ, being influenced by the ages and sexes of the members of the family, their economic status, habits, diet, and the numbers and types of plumbing fixtures connected to the system.

There are no known records of the character of fresh uncomminuted household sewage on the basis of the present usual yardsticks, solids and biochemical oxygen demand. This is due no doubt to the problem of obtaining representative small samples for analysis. Sewage in passing through pipes and sewers becomes comminuted to varying degrees, and sufficiently so in community sewer systems, to make it possible to obtain a small sample, or series of samples, fairly representative of the whole. Thus while much data exist on the character of community sewage, as measured by the usual yardsticks, no similar data has been found for the fresh household sewage. It is hoped that some investigation can be undertaken in this connection in the present Project.

The quantity of sewage which a septic tank will receive during the period of a day will vary considerably depending on those same factors which affect the character of the sewage. The flow to the tank will be intermittent with sharp peaks and long periods during which no flow occurs. In general, for an individual house the quantity of water used will closely approximate the quantity of sewage received by the tank. However, consideration must be given in estimating sewage flows by water consumption data, to any factors which might lessen the quantity, such as watering the lawn, cleaning buildings, watering stock on a farm and diversion of wastes from particular fixtures to disposal other than through the septic tank.

Data on per capita water use for individual houses was presented by Pond in 1939 *Journal of the American Water Works Association*. These data are reproduced in Table 1 below:

TABLE 1.--Daily per capita water consumption in 1 family houses

	<u>Year</u>	<u>Houses</u>	<u>Gal./cap./day</u>
Newton, Mass.	1892	490	26.5
Hartford, Conn.	1920	302	43.8
New Haven, Conn.	1937	1519	59.4
West Haven, Conn. ...	1937	3380	36.8

Pond also gives the following figures for estimating the daily water use:

Basic quantity individual	20 gallons/day	
	(Includes:	drinking ... 1 gal.
		laundry 6 gal.
		ablution ... 5 gal.
		2 toilet
		flushes 8 gal.
Tub bath	25 gallons	
Shower bath	5 gallons	
Additional toilet flush/person .	6 gallons/day	

The quantity of 20 gallons per person per day is considered the minimum necessary to allow normal daily functions. In using these figures for preparing an estimate of water consumption in individual cases, consideration should be given to any factors which might unduly influence the consumption, as automatic washing machines, a very high standard of living, or a large amount of entertaining.

Few data are available concerning the per capita sewage flow from an individual house. Data from the Kansas State College study show an average per capita sewage flow from two farm houses to be 14.5 and 19.2 gallons per day. The maximum days occurred on Monday and Saturday, and the maximum months during the summer. Conclusions given in the Illinois study state that where all of the house supply is discharged to the sewer and none is used for farm purposes, that the sewage is approximately equivalent to the water consumption.

Most State regulations recommend that the sewer line from the house to the septic tank be at least 4 inches in diameter of bell and spigot pipe with tight joints. In those cases where the sewer lines are within minimum distance from water supply sources, the sewer usually must be of cast iron pipe. A 1933 APHA Committee reported that there is some tendency for tree and shrub roots to enter the cracks of sewer lines, and that the joints should be made of materials that will prevent roots from entering. Sulfur base compounds and copper rings have been used for this purpose.

Most states do not require that grease traps be used on septic tank installations for individual houses. Little information has been located concerning the use of such traps in other countries. Oothuizen in South Africa reported on a tank to treat only water closet wastes, and recommended that other wastes be discharged to a leaching cesspool. From the Victoria, Australia survey it appears that most tanks there treat only water closet and urinal wastes. However, no mention is made of the disposition of other wastes. In those cases where grease traps are used, most states recommend that they be installed in the kitchen drain as close as possible to the house.

Various types, shapes, and arrangements of septic tanks have been used since this type of tank was first proposed by Mouras. Detention periods have varied from a few hours to several days in tanks of one and multiple chambers, of rectangular and circular plan, with and without sloping bottoms, and with various types and arrangements of inlet and outlet devices. In Germany, the so-called "fresh-water clarification tank" came into use during the 1920's. This type of tank afforded a detention period of from 1 to 2 hours, and was based on the two story type tank. Later, in Germany and in Poland the trend was toward the use of the old fashioned septic tank with detention periods up to 20 days. The use of the small "fresh-water" tanks has gradually declined. In the United States, septic tank design criteria have varied widely among the different organization publishing information. In recent years the trend has been toward a standardization of design factors, based to a large extent on the work of the Joint Committee on Rural Sanitation.

In the United States, detention periods in septic tanks vary from 12 to 72 hours, with the average being approximately 24 hours. Recommendations by Sierp in Germany and Szniołis in Poland call for a detention period of 3 to 20 days, which is the longest period noted in the literature survey. Temple and Ganguli in India based tank capacities on the criteria of

2 cu. ft. per capita, while in Victoria, Australia, the liquid capacity required is 300 plus 30 N Imperial Gallons (N being the number of persons). In Poland, Szniolis recommends a design capacity of 1 cu. m. per capita (264.2 gallons). In the United States, the usual practice is to provide for 24 hours detention with a sufficient additional capacity to allow sludge storage. Recent information on tank capacities in 47 States indicate minimum liquid capacities ranging from 300 to 1000 gallons, with 34, or 72%, at 500 gallons or above, 8 or 17%, at 400-500 gallons and 5, or 11%, at 300-400 gallons.

The allowances to be made for the accumulation of sludge and scum are usually based on empirical estimates. Ganguli estimates that the average accumulation is 0.5 cu. ft. per person per year, while results of a survey of 35 tanks in California showed that the accumulation of sludge and scum in a rectangular tank was 1.38 cu. ft. per person per year. In the Illinois study, Lehmann found that the accumulation in the three farm tanks over a 2 year 8 1/2 month period was 3.35 cu. ft. per person per year. The California State Health Department recommends an allowance of 20 gallons (2.67 cu. ft.) per person per year. The Joint Committee provides for 20 to 37.5 gallons (2.67 to 5.0 cu. ft.) per person per year.

Little information on the amount of freeboard required is available except from the United States. The State requirements specify between 6 and 24 inches of freeboard, with the average being about 12 inches. Some question has been raised as to the necessity for any freeboard, though no cases have been found where the tank has none. Studies under way at the University of Michigan include investigation of performance without freeboard.

In Poland the septic tank system is vented through the building plumbing stack and also at the end of each tile line, while the usual practice in the United States is to vent only through the plumbing stack. In England, Ferguson recommended that the inlet pipe be vented.

Most of the articles reviewed favored the use of either submerged inlets or baffles to break up the influent velocity, and similar devices for the outlet to prevent scum being carried to the absorption system. Various plumbing fittings such as L's, T's and Y's are used to provide submerged inlets and outlets. Four States recommend no inlet device. Stewart at the University of Minnesota found that a tee with the open ends turned sideways, or a current breaker box, provided the most satisfactory inlet conditions.

Various types of partition walls and scum boards have been used to improve the operation of septic tanks, though none has been generally accepted. In Australia, the Health Department warns against the use of chambers filled with stone, as they provide no treatment. Ganguli recommends the use of a grit chamber 1/6th to 1/8th the length of the tank. Narston and Okey, and later, Peterson, at Iowa State College conducted experiments to develop a self-contained treatment plant which consisted of a septic tank, a sand filter and finally a trickling filter. This is shown on Plate 1.

On the basis of the Illinois experiments, Lehmann et al recommended the use of a two compartment tank. Sierp and Szniolis recommend the use of three chamber tanks regardless of whether they are rectangular or round in plan. Imhoff in *Taschenbuch der Stadtentwässerung* recommends the use of baffles in the tank, presumably to effect compartmentation. Schreiber describes a tank which he developed of four chambers formed in a circular tank by fixed baffles. The first two chambers serve to remove the heavier solids and discharge the solids to a digestion chamber located below. The third and fourth chambers are used to remove the finer material. In the United States, most health authorities recommend the use of a single compartment tank, though six states favor a two chamber tank, while one recommends the use of a three compartment tank (under and over partition walls).

In the United States, all State recommendations favor the use of a rectangular shaped septic tank. Only two States give specifications for round tanks. The usual ratio of length to width employed is between 2:1 and 3:1, and no State recommends a ratio greater than 3:1. In India, Temple recommended the use of ratios of length to width of 6:1 or greater. Victoria, Australia regulations call for a ratio of length to width of 3:1, and a water depth of at least 3 ft. 6 in. The usual minimum water depth recommended in the United States is 4 ft., (41 States - 4' or more, 5 States - 3' to 4', 2 States - unknown). Most foreign articles reviewed favored water depths of approximately 4 ft., though the minimum was 30 in.

Of the research projects conducted in the United States, none carried out any studies using round tanks, nor was any factual information relative to round tanks found in foreign literature. Round tanks are used in Poland, Germany, and India, though in Germany most of the round designs are the "fresh-water" (two story) type of tank.

All States recommended that septic tanks be constructed of materials that are not subject to corrosion, such as concrete, cement blocks or brick. The Joint Committee Recommendations (revised 1947) state that steel tanks should be constructed of 12 gauge metal. Most foreign articles reviewed favor the use of concrete, brick, or stone tanks. In Poland, round tanks are constructed of unreinforced concrete rings of several standard diameters. The tank may then be made as deep as is desirable by the use of additional rings.

In Appendix A will be found several selected septic tank designs to show the variation in tank types encountered. Three State health department tanks are shown as well as samples of the European "fresh-water" type of tank.

In the United States, dosing siphons are not generally used except for large installations. Where such siphons are used it is generally recommended that they be of such size as to fill the tile of the field one-half to three-quarters full at each discharge of the siphon. No information was available from foreign countries concerning the use of dosing siphons. Sierp in *Lebensmittel Chemie* states that ground absorption of septic tank effluent can be improved by providing sufficient aeration, and that this can best be accomplished through the use of a dosing device.

The purpose of a distribution box is to distribute evenly the tank effluent to all lines of the tile field. The use of a distribution box is recommended in most State regulations. This box may also be used as an inspection manhole to determine if sludge particles are being carried to the tile field. It may also serve in connection with alternation of tile lines. A tank design in the *New Zealand Journal of Agriculture* showed a distribution box cast as an integral part of the tank structure. Szniolis stated that distribution boxes were not used in Poland.

Most information concerning the disposal of septic tank effluent is available from the United States. Some information from other countries is available, though it is very meager and quite indefinite. Except in special circumstances, the usual method of disposal of the effluent is by means of a subsurface tile disposal field with ground absorption of the effluent. Such systems are usually composed of one or more lines of drain tile laid in gravel, about 18 inches below the ground surface. Most States recommend the use of common 4 in. agricultural drain tile for constructing this system, and a few permit the use of V-shaped troughs of rot-resistant wood. The 1933 APHA Committee Report suggested the use of a 12 in. concrete pipe split lengthwise and laid on a bed of gravel. In addition to these materials, perforated fiber conduit, perforated bell and spigot tile pipe, and perforated concrete tile are available. Ordinary agricultural tile are usually laid on a grade of 2-4 in. per 100 ft., though the State regulations vary considerably. The maximum allowable grades vary from 1 to 12.5 in. per 100 ft. The tiles are usually laid with a spacing of 1/4 to 1/2 in., and this opening is covered with tar paper or in some cases pieces of galvanized metal. In South Carolina in a sandy area, it was found that the first 25 to 30 ft. of a tile line clogged quite rapidly when ordinary grades of 2-4 in./100 ft. were used. To alleviate this difficulty steep grades are used (12-18 in./100 ft.) in the first half of the tile lines.

The average minimum trench width recommended by the State recommendations is 18 in., though these vary from 10 to 24 in. The tile is usually located about 18 to 24 in. below the ground surface. In one state the preferred depth of cover is 60 in., while in another it is 10 in. It is general practice to recommend surrounding the tile with gravel. Recommendations as to the amount of gravel vary from 20 in. to a very small amount under the tile, and from none to 6 in. over the tile. The Joint Committee report recommends that at least two lines of tile be used for a field, though only three States made this same recommendation. Nineteen States make recommendations concerning the length of individual tile lines, and these maximum lengths vary from 50 to 200 ft. with the average being approximately 100 ft. State recommendations on the minimum spacing between tile lines vary from 3 to 10 ft. with the

average being about 8 ft. The Joint Committee recommends that the spacing be at least three times the trench width with a minimum spacing of 6 ft.

It is the usual practice in this country to vent the septic tank system through the building plumbing stack with some aeration occurring through the soil. In Poland the usual practice is to vent through the plumbing stack, and also provide a vent at the end of each tile line. This same system is recommended by Sierp in Germany.

The amount of tile required to satisfactorily dispose of the effluent is the subject of the most variance in State recommendations. This is discussed further later in the report. Some States base their requirements on length of tile for a particular system, while others express it in feet of tile per person or bedroom. In addition, requirements are sometimes expressed in square feet of absorptive area, the assumption being that the area of the bottom of the trench is the effective absorptive area. Based on feet of tile per system, the recommendations vary from 70 to 500 ft. depending on the nature of the soil. Recommendations on a ft. per capita basis vary from 12 ft. to 100 ft. for soils of coarse sand or gravel to clay with some sand or gravel. In most cases the use of tile fields in clay soils is deemed unsatisfactory. The Joint Committee report recommends that tile field requirements be based on absorptive area determined by soil percolation tests and using the maximum living capacity of the dwelling concerned.

The percolation test was originally proposed by Henry Ryon in an unofficial publication of the New York State Department of Health. Since then it has been widely adopted. The test is based on the absorption of water from a 12 in. square hole dug to the depth of the trench. The amount of tile or absorptive area required may then be determined from the chart after observing the time required for water to fall one inch in the hole. The percolation test values of the Joint Committee are similar to Ryon's, though they differ in the upper ranges, and omit the faster rates of percolation taking 2 min. per inch as the minimum rate. The absorptive areas in sq. ft. per bedroom recommended vary from 50 to 240 sq. ft. for 2 min. per inch and 60 min. per inch fall, respectively.

Most States recommend the use of subsurface tile systems rather than seepage pits, although pits are permitted under various circumstances in most States. Sometimes, they are used to supplement the tile disposal system, though they may be used as the only method of disposal. They are most often used where the surface soil is very tight and where a relatively porous soil underlies this. The Joint Committee report recommends that the capacity of a seepage pit be at least equal to the capacity of the tank, and, in tight soils, twice the tank capacity. In most cases, seepage pits are lined with brick or stone.

Several States recommend that a subsurface sand filter be used in soils which will not readily absorb the effluent from an ordinary soil absorption system. With this type of disposal system, provisions must be available for disposing of the filter effluent to a natural water course. The distribution tile is usually laid in 6 to 8 in. of gravel at about the same depth as the tile in a filter trench. Under this is located from 1 to 3 ft. of coarse sand, and the effluent is collected by another tile line laid in gravel. The usual depth of sand is about 24 in. The usual allowable rate for dosing these filters is approximately 1 gallon per sq. ft. per day. Some States express these requirements in sq. ft. per person. Two States require a minimum filter area of 300 sq. ft. In some cases the distribution tile are vented to the ground surface, and the filter may only be used in connection with a dosing siphon.

One State recommends that a chemical toilet or privy be used when impervious soils are encountered.

Various other types of secondary treatment have been used for septic tank effluent. In Poland, small trickling filters, or 30 minutes contact with a solution of calcium hypochlorite are often used where soil conditions are such that a subsurface tile field can not be used. Szniolis also mentioned the use of high pressure sprays which are used to spread the effluent over farming areas. Marston and Okey and later Peterson at Iowa State College designed a septic tank with a sand filter and trickling filter built as an integral unit. In Public Health Bulletin No. 101, Frank and Rhynus describe a lath trickling filter, which

they recommend for use in small installations in preference to stone filters. They state, however, that some form of distributing device must be provided, and describe several types in this paper. Present practice in the United States usually recommends that these methods of secondary treatment be used only when it is impossible to secure treatment by soil absorption.

It appears that freezing in septic tank systems does not occur as frequently as thought, and that shallow systems are much in evidence in the northern part of the country. Flood in New England stated that systems had been built there with 18 to 24 in. of cover, and they had operated satisfactorily for a period of years. A detailed examination of data solicited on the freezing aspects of shallow systems is given in a later section of this report.

The disposal of ground garbage through a septic tank system introduces an additional factor to be considered in septic tank design. Estimates based on a literature review show that the average per capita garbage production is approximately 0.65 lb. daily. This figure is subject to much variation, however, and may be affected by seasonal and geographic conditions. Consideration must be given to the increased quantities of sludge, scum, and grease discharged to the tank, and to the effects of the increased solids loading on the effluent disposal system. The Joint Committee recommends that the septic tank capacity be increased 50 per cent where domestic garbage grinders are involved.

Various proprietary materials are available for use in cleaning toilet bowls, sinks and clogged drains. Both acid and alkaline compounds are used for these purposes, and the continued use of such materials in large quantities could of course affect the bacterial life in a septic tank. Reports of tests conducted by consulting chemists for two of the largest manufacturers of these materials indicated that when used according to directions, their particular cleaners produced no ill effects on septic action.

There are materials available which purport to increase, restore, or continue septic action in a septic tank. One product which was analyzed consisted of dried yeast, and sold for \$1.00 for 4 ounces. Another product at \$4.95 per gallon was thought to be sodium hydroxide. Reports have been received that yeast has been used to a considerable extent, and many laymen are of the opinion that this material starts and keeps a septic tank working well. The results of laboratory investigation of tank seeding, including application of yeast, appear in Section E of this Report. Several authors recommend the practice of seeding the tank with septic sludge both when a tank is placed in operation and after cleaning.

EXPERIMENTAL AND SURVEY STUDIES

The experimental and survey work carried out on household septic tank-soil absorption systems since their inception is limited. Starting with the Mouras-Moigno work before 1881, the list of projects noted includes studies made by the University of Illinois Agricultural Experiment Station and the State Water Survey, the Kansas State Agricultural College; Iowa State College, the State Health Department of Massachusetts and Michigan, the University of Minnesota, the Victoria, Australia Department of Health, and the American Public Health Association. Current studies include, besides the H.H.F.A. Project, experimental study of septic tanks at the University of Michigan and at the University of Illinois, and, a study of the application of sewage to soils at Rensselaer Polytechnic Institute. Some recent work has been done at the Massachusetts Agricultural Experiment Station but so far as is known this has not been published.

References to experimental work in Germany and in India have been noted, but search of the literature has failed to produce any factual reports of their studies.

In the pages following there is presented a resume of some of the experimental and survey studies for which information is at hand, followed by a section on design practices including design recommendations of the States, and design recommendations in a number of foreign countries.

Illinois Study

In 1928 Lehmann, Kelleher and Buswell (294) reported the results of a study concerning the factors affecting the efficiency and design of farm septic tanks conducted at the University of Illinois. This project was carried out as an active research project from 1922 to 1925, and certain phases were continued until 1944. The accumulation of sludge and scum in the three farm septic tanks used in this project has been noted in the annual reports of the Illinois Agricultural Experiment Station for 1934, 1935, 1936, 1937, and 1938.

This project was divided into two separate phases. In the first phase experimental tanks of the same cross section and capacity but with different methods of compartmentation were tested. The second phase of the study used two compartment tanks of the same capacity and length but with differently shaped cross sections. In the first phase two tanks in use at farms and of the same design as the experimental tanks were operated, and in the second phase these farm tanks were used which were identical with those treating city sewage. The experimental tanks were dosed four times a day with Champaign city sewage, and grab samples for chemical analysis were taken from each chamber of each tank every six days.

During the first part of the study the experimental tanks were operated from 1922 to 1923, and the two farm septic tanks were placed in operation at approximately the same time. All experimental tanks were 12 ft. long, 3 ft. wide with a 4 foot water depth. One tank was operated as a single chamber unit, another divided into three equal chambers and the third had two chambers, the first being two-thirds of the total capacity. The two chamber tank gave the best results during the year's operation. It was further concluded that for tanks having a 72 hour detention period there was an advantage in using two chambers, but for tanks having a 48 hour detention period two chambers were of no advantage. The curves showing tank temperature, turbidity, residue of evaporation and settleable solids plotted against time indicate that the effluent was relatively high in solids during the Summer months when the tank temperature was high.

The second phase of this study concerned itself with the effect of difference in shape of cross section on the efficiency of septic tanks. All the experimental tanks were of the same capacity and each had two chambers. The first chamber of each tank was 8 ft. long and the second was 4 ft. long. The tanks were of the following cross sections:

- 2.4 ft. wide by 5 ft. water depth
- 3 ft. wide by 4 ft. water depth
- 4 ft. wide by 3 ft. water depth

Three tanks connected to university farms, and similar to the experimental tanks, were constructed. The experimental tanks were dosed as in the first phase of the experiment with 359.5 gallons of sewage per day, which was equivalent to a total detention period of 72 hours. These tanks were operated during 1924 and 1925. The conclusions were that no definite relationship existed between the shape of cross section of a tank and its operating efficiency. These experiments confirmed the first phase results in showing that a two chamber tank was more efficient than a single chamber tank of a third less capacity.

During the second phase of the experiment accurate records of the accumulation of sludge and scum in the farm septic tanks was started. The collection of this data was continued until the early part of 1941, when personnel shortages caused it to be discontinued. The average accumulation of sludge and scum per tank during a 2 year 8-1/2 month period was 3.35 cu. ft. per person per year. Table 2 following shows the data reported by Lehmann in his annual reports. The figures showing sludge accumulated are averages of all readings taken during a year's period. This method of analyzing the data does not produce the results which might be expected had a mass curve method of analysis been used. Plate 2 presents the data from February 17, 1937 to February 26, 1944 and is based on data as collected. This material was furnished through the courtesy of Prof. Lehmann.

The design recommendations given in the Illinois report were as follows:

Min. number of persons: 7

Flow: 7 persons, 25 gpd
9 persons, 23 gpd
12 persons, 20 gpd
15 persons, 18 gpd

Min. detention: single chamber tank
48 hrs. + 50% sludge storage
--two chamber tank
72 hrs. 1st chamber
36 hrs. 2nd chamber

Tank width: 3 ft.
Water depth: 4 ft.

The two chamber tank was recommended as being more satisfactory than the single chamber one.

TABLE 2.--Relative Efficiency of Three Two-Chamber Septic Tanks of
Different Cross-Sections, as Measured by Accumulations of
Sludge Over a Period of Fourteen Years

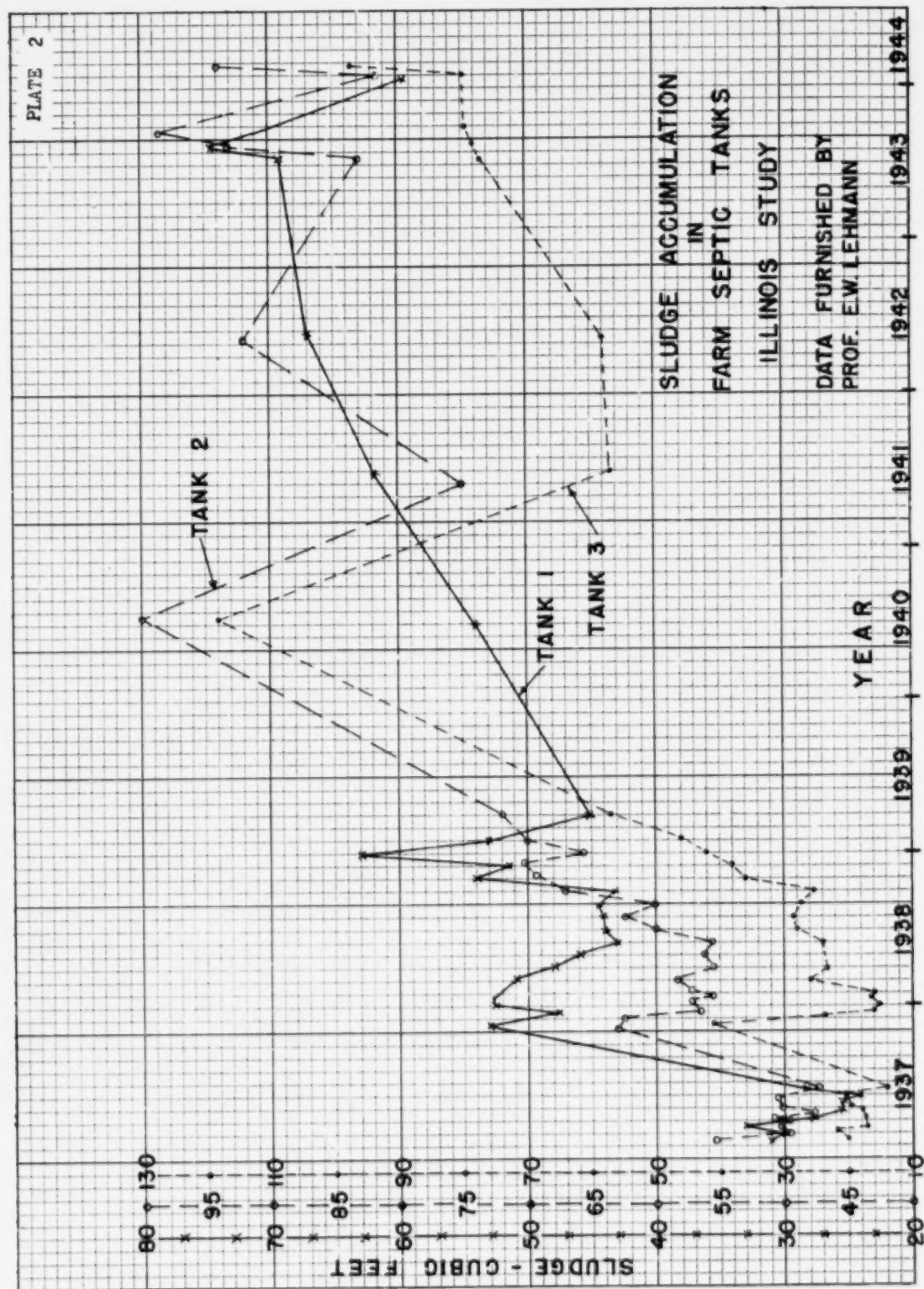
Sludge Over a Period of Fourteen Years																					
Tank	Tank dimensions		Number of Persons	Sludge Accumulated								Average for each person a year									
	Depth	Width		1931 ¹	1932	1933	1934	1935	1936	1937	1938	1924		1931		1933		1935		1937	
												feet	feet	feet	feet	feet	feet	feet	feet	feet	feet
1	5	2.4	3 ²	25.44	31.59	31.51	41.28	34.20	29.90	25.44	47.31	1.16	1.01	.45	1.46	7.20					
2	4	3.0	9 ³	44.00	42.84	51.55	56.04	69.00	56.53	48.88	56.89	2.86	1.88	1.81	1.12	.99					
3	3	4.0	7	69.29	77.76	83.43	88.16	110.00	Filled	12.26	23.21	.96	.71	2.21	1.75 ⁴	1.57					

¹The column for 1931 includes the time from June 1, 1930, thru May 31, 1931.

²Tank 1 was used by three adults until September 15, 1937, it was then idle until April 31, 1938, when two adults and one small child began using it.

³Of the nine persons two were adults and seven were children.

⁴This is the amount of 1936-37 instead of an average for two years.



Kansas State College Study

In 1929, Walker and Driftmier (318) reported the results of their studies of the septic tank method of sewage disposal for isolated homes. Two previous reports (197) (204) were made concerning the aims of the project and the sewage flow characteristics from farm homes.

The studies at the Kansas State Agricultural College were conducted on two separate tanks located on farms at the college. The Agronomy Farm installation was a 620 gallon single chamber rectangular tank 6 feet long, 3 feet 6 inches wide, and 4 feet water depth with a baffled tee inlet and a baffled weir outlet. Later in the study this tank was divided into two chambers, the first being two-thirds of the total tank. The baffle boards were also sloped toward the end walls at this time. The Poultry Farm installation was a 300 gallon single chamber rectangular tank with a direct side inlet. The inlet had a sloping baffle and the outlet was a weir protected by a sloping baffle. The tank was 4 feet long, 2 feet 6 inches wide and 4 feet water depth. Both tanks were equipped with automatic dosing siphons.

A recorder mounted over the siphon chamber was used to record the fluctuations of the water level in this chamber. A week's record of the sewage effluent flow was obtained on each chart. The four graphs on Plate 3 indicate the major information reported. No analysis was given of the hourly fluctuations in flow. An attempt was made to obtain this original data for analysis, but it has evidently been destroyed according to information received from present officials at the college. This instance is the only one known where a study of the rate of sewage flow from an individual home has been made.

Temperature records for the Poultry Farm installation show that the sewage temperature followed the atmospheric temperature fairly closely, though abrupt changes did not occur in the sewage temperature. The sewage temperature varied from 48° F. to 73° F.

The thickness of scum after formation on the Poultry Farm tank varied from 6 inches to 18 inches with the maximum thickness occurring shortly before the maximum temperatures. The results of two scum analyses are given in Table 3.

TABLE 3.--Analysis of Scum

	<u>1/25/27</u>	<u>4/9/28</u>
Net weight received	¹ 1090 gra.	² 1809 gra.
Net weight dry	628 gra.	338 gra.
Per cent dry matter	56.6	18.68
Per cent water	42.2	81.32
Nitrogen as protein	15.90%	15.94%
Fat	9.41	6.37
Fiber	5.64	6.42
Moisture	2.68	1.47
Ash	34.89	49.57
Nitrogen free extract		
Sugar, starch, etc.	31.48	20.23
Nitrates	None	None
Nitrites	None	None

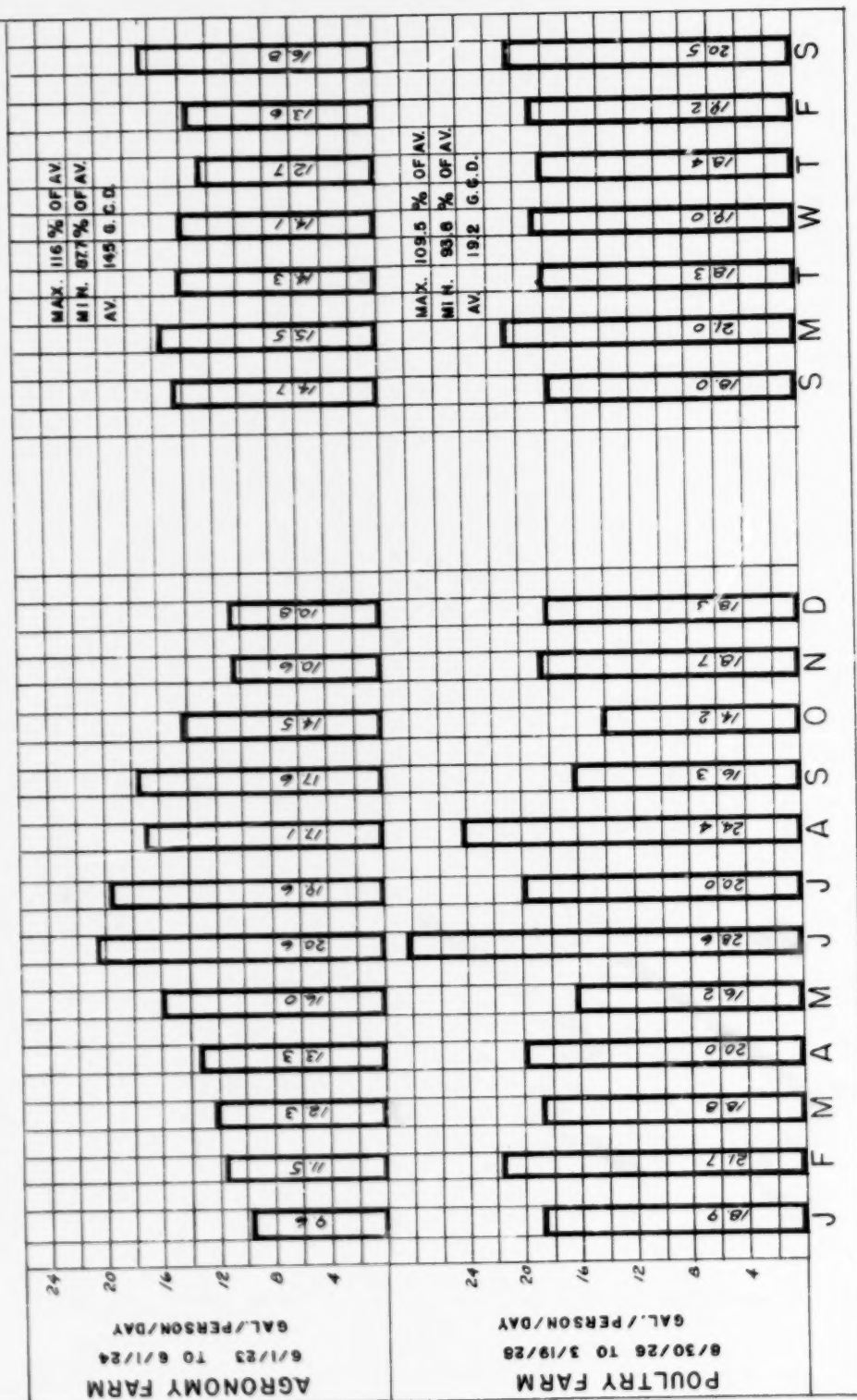
¹Air dry sample

²Sample as taken from tank

The average weekly retention period in the septic chamber was calculated for the Poultry Farm tank. It varied from a minimum of 35 hours to a maximum of 92 hours with an

AVERAGE DAILY FLOW

AVERAGE MONTHLY FLOW



average of 60 hours. The data show that the suspended solids in the effluent increased as the detention period became shorter, and conversely. It was concluded that the detention period should be between 60 and 80 hours to secure optimum results.

Data were presented given the results of bacterial and chemical analyses. However, the method used in sampling, the frequency of sampling, and the points from which samples were taken are not given.

These studies present data not available from other work, and the program of study shows an excellent approach to a solution of the problem. However, the data appear too limited to warrant any broad conclusions.

Iowa State College Experiments

Studies of sewage disposal plants for private houses were started in 1904 at the Iowa State College Engineering Experiment Station by Marston and Okey (44). Additional studies were conducted by Peterson in 1941 (552).

In Marston's experiments several types of plants were studied during the five years of this Project. In attacking the problem the differences between city treatment plants and home disposal plants were carefully noted, and considered in preparing designs investigated. These fundamental points were the extreme variations in flow, the small size of the tank, the fresh character of the sewage and fluctuations in quantity, the lack of proper maintenance, and the proximity of private plants to dwellings.

The general conclusions of this study were:

- (a) The size of the sewage tank must be much larger per person than in the case of city plants.
- (b) The disturbing effect of the inflow into the tank must be destroyed.
- (c) The effluent must be removed without disturbing the tank contents.
- (d) Mechanical equipment must not be used.
- (e) The filter area per person must be substantially increased over that required in a city plant.
- (f) It is impracticable to secure an effluent comparable to that from a city sand filter plant.

The final tank design proposed by Marston and Okey consisted of two concentric circular tanks. The outer tank had a septic chamber comprising $1/6$ of the total volume of the outer well. From the septic chamber the sewage flowed over a weir onto a four inch thick sand filter which comprised the other $5/6$ of the outer well. The sand filter was supported by a reinforced concrete slab with small conical shaped holes which served as a sprinkling device for a trickling filter located below. The effluent from this filter was piped to a drainage ditch or natural water course. The inner well served as a ventilating shaft for the trickling filter.

Peterson's studies were made using a modified form of this type plant. This system consisted of a septic tank and upward flow of six inch sand filter with final treatment on a small trickling filter. The design developed by Peterson was in the form of a rectangular tank with the sand filter supported on a lath screen and hanging in the septic tank. The partition wall of the filter serves in effect as a scum board and under this a wood baffle prevents the sludge from entering that part of the tank under the sand filter. The tank developed by Peterson is recommended by the Engineering Extension Service of Iowa State College (585).

A.P.H.A. Committee--1933

In 1933 a committee of the American Public Health Association reported (383) the results of a survey of 35 demonstration farm sewage disposal plants. These tanks were built and surveyed by the Agricultural Extension Service of the University of California.

The tanks were of a rectangular concrete design conforming to the following dimensions:

<u>Persons</u>	<u>Length</u>	<u>Width</u>	<u>Depth</u>	<u>Water Depth</u>
10	7 ft.	3 ft.	4 ft.	3 ft.
16	9	3.5	4	3
20	10	4	4	3

Tee inlet and outlet arrangements were branch Y's, with sloping scum boards in front of the inlet and outlet. A partition board 30 inches high was placed 18 inches from the outlet end.

The conclusions resulting from an analysis of the data included:

(a) The average rate of accumulation of sludge is about 1 inch per person-year for the first 20 person-years in the tanks 7 feet long, 3 feet wide and 3 feet effective depth.

(b) The tanks should be cleaned out prior to 18 person-year use to avoid rapid accumulation of sludge in the effluent pipe lines.

(c) There is a tendency for shrub and tree roots to enter cracks in the cemented joints of the sewer line.

(d) Open-bottom seepage systems of concrete irrigation pipes (12 inches diameter) split lengthwise have given good results in a large number of installations in one county.

Strips of 1 x 4 durable lumber should be laid under the split concrete pipe to prevent settling of joints if fine gravel is used. Inverted troughs of durable wood in the shape of the letter V will give the same results as the split pipe.

Part of the data obtained during this survey has been furnished by H. L. Belton of the University of California and is shown in Table 4. The rate of accumulation in cubic feet per person per year was computed from the original data.

TABLE 4.--Rate of Sludge Accumulation

Tank Number	Persons	Years	Person Years	Depth Inches	Sludge Rate of accumulation	
					inch depth/ person/year	cubic feet person/year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2	4	6	24	24	1.00	1.75
6	3	6	18	19	1.06	1.86
9	6	5	30	18	0.60	1.05
10	2	6	12	20	1.66	2.91
11	2	6	12	14	1.17	2.05
12	5	8	40	26	0.65	1.14
14	5	9	45	27	0.60	1.05
16	3	4	12	10	0.83	1.45
17	4	3	12	11	0.91	1.59
20	3	5	15	14	0.93	1.63
21	3	4	20	11	0.55	0.96
25	7	7	49	26	0.53	0.93
26	4	5	20	12	0.60	1.05
27	4	8	32	24	0.75	1.31
28	4	4	16	9	0.56	0.98
29	2	5	10	8	0.80	1.40
30	3	7	21	9	0.48	0.84
31	4	7	28	29	1.04	1.82
33	5	7	35	25	0.52	0.91
34	6	7	42	21	0.50	0.88
Average					0.782	1.378

University of Minnesota Experiment

Investigations at the University of Minnesota reported by Stewart (215) in 1924 concerned the development of a low-cost homemade siphon, and the design of inlet devices for septic tanks. A small one-fourth size experimental tank having glass observation windows was used for developing a satisfactory inlet design.

Four types of inlets were tested; (1) simple elbow; (2) elbow and tee with joints of the tee turned sidewise; (3) baffle boards; and (4) current breaker chamber. Types 1 and 3 proved unsatisfactory since the incoming sewage produced a great deal of agitation in the tank, stirred up the sludge on the bottom and carried it away from the inlet end of the tank, and produced a very uneven distribution of sludge over the bottom of the tank. Types 2 and 4 produced very satisfactory results. The current breaker chamber is a small rectangular chamber into which the sewage discharges and from there is admitted to the septic tank through two submerged ports.

According to this report, the studies were continuing with the improvement of the tank design as the next step. However, no further information concerning this project could be located in the literature.

Victoria, Australia Survey

The results of a survey of 1088 septic tank systems by the Victoria, Australia Department of Public Health was reported by Hepburn (461) in 1936. An initial report of the survey was made (395) in 1933. Only the physical aspects of the systems were noted in this survey, and chemical sampling was not used. For the final tabulation of results only those surveys pertaining to individual dwellings were used, and these totaled 726 tanks.

The criteria used in classifying a tank as satisfactory or not were:

- (a) The tank should operate for three years before requiring cleaning.
- (b) The tank should not, within this period, discharge suspended matter in quantities that will interfere with filter operation or choke the pores of soils around a sub-surface disposal system.
- (c) The tank should not give off offensive odors.

In considering the data reproduced from this report, it should be remembered that gallons are Imperial gallons (Imp. gal. $\times 1.2 =$ U.S. gal.), and that the tanks surveyed received wastes from water closets and urinals only. The flow carrying these wastes seldom exceeds 10 gallons per capita, and is usually about 6 gallons per capita. The data were analyzed in terms of various factors which influence tank operation. These include capacity, water depth, shape, type, and surface area.

Capacity.--The range in tank sizes is shown in Table 5.

TABLE 5.--Tank Capacity, Total

	Capacity in gallons						
	Up to 100	101 to 200	201 to 300	301 to 400	401 to 600	601 to 1,000	Over 1,000
Number of tanks	141	137	118	100	114	57	58
Per cent of total	19	19	16	14	16	8	8

An analysis based on per capita capacity is given in Table 6.

TABLE 6.--Tank Capacity, Gallons per Capita

Capacity/person in gallons																
	Up to 10		11 to 20		21 to 30		31 to 40		41 to 50		51 to 100		Over 100		Total	
	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Number of tanks	1	21	17	90	35	80	30	51	28	28	121	55	164	5	396	330
Per cent satisfactory	4.5		16		30		37		50		69		97		54.5	

Note.--In all tables S = satisfactory, and N = unsatisfactory

Based on the fact that a high percentage of satisfactory tanks is not reached until the capacity exceeds 100 gallons per capita, the author attacked the premise of fixing tank capacity on a per capita basis. He states that basing tank capacity on per capita contribution is applicable only over a very small range in the number of persons served.

To obviate erroneous conclusions, the data were analyzed to show the percentage increase in satisfactory tanks as the basal capacity was increased. The basal capacity "C" was obtained by subtracting from the tank capacity the assumed daily flow, 10 N (N being the number of persons served). Table 7 shows this analysis.

TABLE 7.--Basal Capacity

	Basal capacity in gallons														Total	
	Under		51 to		101 to		151 to		201 to		251 to		301 to		Over	
	50		100		150		200		250		300		400		400	
	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Number of tanks	7	132	17	77	21	31	38	32	35	23	34	13	69	11	175	11
Per cent satisfactory	5		18		40		54		60		72		86		94	

Note.--In all tables S = satisfactory, and N = unsatisfactory

From this table the author concludes that a tank having a capacity in excess of 300 + 10 N would prove satisfactory if the other details are not grossly bad. (Assuming 4 persons the capacity would be: $300 + 40 = 340$ Imperial gallons, or $340 \times 1.2 = 408$ U. S. gallons).

Depth.--The tabulation of tanks on the basis of depth is shown in Table 8.

TABLE 8.--Depth

Depth below water line								
		2 feet 1 inch to 2 feet 6 inches	2 feet 7 inches to 3 feet	3 feet 1 inch to 4 feet	4 feet 1 inch to 5 feet	Over 5 feet	Total	
	S N	S N	S N	S N	S N	S N	S N	
Number of tanks	24 166	41 54	102 56	159 46	50 6	20 2	396 330	
Per cent satisfactory	13	43	65	78	89	91	54.5	

Note.--In all tables S = satisfactory, and N = unsatisfactory

As depth and capacity are usually interrelated, the author next analyzed the data using only those tanks in which the basal capacity exceeded 200 gallons. This eliminated those tanks which were undoubtedly of insufficient capacity. This analysis is shown in Table 9.

TABLE 9.--Depth (Basal Capacity in Excess of 200 Gallons)

		Depth below water line							
		2 feet 1 inch to 2 feet 6 inches	2 feet 7 inches to 3 feet	3 feet 1 inch to 4 feet	4 feet 1 inch to 5 feet	Over 5 feet	Total		
		S N	S N	S N	S N	S N	S N	S	N
Number of tanks	5 2	11 5	83 22	152 22	47 7	15 1	313 59		
Per cent satisfactory	71	69	79	87	87	94	84		

Note.--In all tables S = satisfactory, and N = unsatisfactory

It was concluded from the depth examination that tanks having a depth of 3 feet 1 inch or greater were usually satisfactory, and the mean depth of 3 feet 6 inches was taken as the minimum satisfactory depth for a septic tank.

Shape.--An attempt was made to analyze the data from tanks with a depth of 3 feet or more, and a basal capacity in excess of 200 gallons, to determine the effect of shape. However, no conclusive results were obtained. Data reported in 1931 by Cole (352) was used, and is from one municipality. All tanks had two chambers, but varying ratios of length to width. This data is given in Table 10.

TABLE 10.--Ratio, Length to Width

		1:1	1½:1	2:1	3:1	4:1	Total
		S N	S N	S N	S N	S N	S N
		3 3	8 9	9 9	15 8	16 2	51 31
Per cent satisfactory		50	47	50	65	89	62

Note.--In all tables S = satisfactory, and N = unsatisfactory

The author concluded from this table that the best proportion in plan for a tank is a length of at least four times the width.

Type.--Next, the tanks were divided into four groups and tabulated using only those tanks in which the basal capacity exceeded 200 gallons and the depth exceeded 3 feet. Tanks in the four groups identified below are compared in Table 11.

Type A. Single chamber

Type B. Two approximately equal chambers

Type C. Large first chamber and one or more small secondary chambers

Type D. Tanks with multiple "under and over" baffles.

TABLE 11.--Type of Tank

	Type of tank									
	A		B		C		D		Total	
	S	N	S	N	S	N	S	N	S	N
	85	15	76	9	99	15	16	7	276	46
Per cent satisfactory	85		89		87		70		86	

Note.--In all tables S = satisfactory, and N = unsatisfactory

From this table the author concludes that only Type D was shown to be less efficient than the other types, but that from the inspection reports of the measurement of sludge and scum additional conclusions could be reached. Type B tanks were found to be uneconomical as the second chamber never collected more than 6 inches of sludge and no scum. The author states that observation of the effluent showed that from Type A tanks was always visibly turbid, but that the effluent from Type C tanks usually contained only minute suspended particles. The author makes the following recommendations with regard to type:

(a) A tank over 8 feet long should have two chambers, the first two to four times the capacity of the second.

(b) A tank 6 feet or less in length should be in the form of only one chamber.

(c) A tank 6 to 8 feet long may be either type, at the discretion of the designer.

Surface area.--An attempt was made to correlate the satisfactory operation of a tank with the surface area, but no relationship was found.

Tank details.--The author found the most effective form of inlet for a small tank to be a tee with its lower end about 18 inches below the water level, and the upper end in the air space. He also states that the cost of desludging can be reduced by sloping the bottom of the tank to the inlet end.

The departmental rules formulated from the results of this investigation are discussed in a later section of this report.

Freezing Studies, Ontario Agricultural College

Graham (167) conducted temperature studies on one septic tank in 1921 at Guelph, Ontario. The tank served the Physics Building at the Ontario Agricultural College. Graham states that the tank received large quantities of water from the automatically flushed urinals, and that the tank temperatures may be expected to be lower than in a tank treating sewage from a private dwelling. Temperatures were taken by recording instruments in the first and second chambers of the septic tank, in the tile line 2 feet below the ground surface, and in the air 3 feet above the ground. Part of the data are reproduced in Table 12.

TABLE 12.--Temperatures

Month	Air Temperature			Temperature in Tile 2 feet deep			Temperature in first Chamber			Temperature in second Chamber		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
December	22.0	42	-4	39.4	44	34	52.9	60	46	44.3	55	35
January	16.8	37	-5	39.3	44	35	52.6	71	44	42.3	56	34
February	21.1	37	-6	40.8	44	37	52.8	58	48	46.5	52	42

From an examination of the graph of all the records, it was noted that the temperature in the tile during these three months was quite constant, however the temperatures in the septic tank followed the changes in air temperature, though not to the extent of nor as abruptly as the air temperature changes.

In conclusion Graham stated that a continuation of the study was planned, but no further references have been located. According to recent information from this college no further experimental work was carried out by Prof. Graham.

Soil Studies--England

In England McGowan and Finlow in the 4th Report, Royal Commission on Sewage Disposal Fowler and Crawford (63) reported in 1904 and 1912 respectively on methods of classifying soils for the land treatment of sewage. In the first study a mechanical analysis was used while in the later one several other methods were investigated.

McGowan and Finlow reported that the results of mechanical analyses "indicate that the maximum number of particles per gram of soil, which is allowable if the filtration is to be efficient (a suitable subsoil being assumed), is somewhere about 1,000 millions." Caution was urged in applying this standard in determining soil suitability.

Fowler and Clifford attempted to develop a method of testing soil suitability other than by mechanical analysis. Various methods and devices were used including a variable pressure porosimeter, a constant pressure porosimeter, percolation experiments, mechanical analysis, volume contraction of soils, and water content of soils.

While the data were not sufficient to allow conclusions to be drawn, it was demonstrated that the relative porosity of sandy soils can be determined by use of a device for passing air through an isolated portion of soil. No attempt was made in this report to conduct the various types of tests on the same soil at the same time. The data presented would have been more valuable if there were a common basis of comparison. This report is mainly interesting because of the variety of methods described for determining soil suitability.

Michigan Department of Health

About 1920, the Michigan Department of Health conducted experiments on flow through a septic tank, operating a standard size tank with one glass side and using dye to trace currents under the influence of the various types of inlets, outlets and baffles used. The results of these experiments were never published and the details are not available. However, the study influenced the Department to eliminate all inlet structures, either of the pipe or baffle type.

It might be of interest here to add that three other states, Nebraska, New Mexico and North Carolina, also eliminate inlet appurtenances from design recommendations.

Massachusetts Department of Health

The Lawrence Experiment Station of the Massachusetts Department of Health has operated small experimental septic tanks for a number of years, some dating back to 1920. So far as is known, no comprehensive report of the series of studies has been published. The following is summarized from brief accounts of two particular years' operation, at hand from annual reports of the Health Department. Two rectangular tanks, one a single compartment, the other, two compartments, with total capacity of 185 and 370 gallons respectively, were operated in 1923 at theoretical detention periods of 2 days each (which, assuming a per capita sewage contribution of 50 gallons per day, would approximate 2 and 4 person volumetric loadings respectively, without allowance for sludge space). The first tank received fresh household type sewage from the Station, the second, Lawrence City sewage. Average suspended solids characteristics were, respectively, for the two tanks: raw sewages, 207 and 192 p.p.m.; effluents, 63 and 38 p.p.m.; removals, 70 and 80 percent. In 1941, four tanks, the

first a single compartment, and the remainder two compartments each, with total capacities of 185, 370 and 370, respectively, were operated. The first tank received Station sewage and the remainder, Lawrence sewage. Theoretical detention periods were 2, 2, 6 and 1/2 days (which would approximate volume loadings from 2, 4, 1 and 15 persons respectively, without sludge storage space allowance, at an assumed 50-gallon per capita per day contribution). Average suspended solids characteristics were respectively: rawsewages, 699, 219, 178 and 183 p.p.m.; effluents, 88, 62, 51 and 70 p.p.m.; removals, 87, 72, 71 and 62 percent.

DESIGN PRACTICE

Information regarding usual practice in the design of septic tank systems of sewage disposal has been procured from a number of countries. In this report each country will be treated separately, and the practice as outlined in the available literature will be given. The material for some countries is quite extensive, while for others only one reference was available. In all cases the source and extent of the data are noted.

With the exception of Germany, practically all countries use a rectangular tank. For Germany the situation is somewhat confused due to a large number of patented designs, and the use of the so-called "fresh-water clarification tank". The tank capacities recommended in different countries vary widely, and the wastes entering the tank do not always include all household wastes. Many references recommended that only water closet and urinal wastes be discharged to the septic tank. Very little information is included concerning the disposal of the tank effluent, and methods mentioned include land disposal as well as treatment on filters or discharge to a watercourse.

United States

In the United States two groups of workers have been active in the field of sewage disposal by the septic tank method. The various State and local health departments have been interested in this problem as part of their general programs, and the agricultural colleges and agricultural extension services have endeavored to promote the use of septic tank systems in rural areas. Due to the multiplicity of agencies and organizations involved, and the variance in local conditions, numerous types and designs of septic tank systems have been promoted. In addition to official governmental agencies, manufacturers of septic tanks have further added to the variety of designs. In view of the limited factual information in this field it is not surprising that conflict of opinion, and confusion, result.

In recent years the Joint Committee on Rural Sanitation, including in its membership representatives of the Conference of State Sanitary Engineers, the U. S. Department of Agriculture, Tennessee Valley Authority, Federal Housing Administration, Geological Survey, and the Federal Security Agency, Office of Education, and the Public Health Service, has brought some uniformity into this field through the assembly of information, its examination, and subsequent preparation of design recommendations. These have received rather wide acceptance over the country, have served in whole or part as a guide for the preparation of recommendations in some States, and are the basis of the Federal Housing Administration basic specification on design.

A review of State recommendations follows. Most of the State bulletins upon which the tables and discussion are based were received in late 1946 and in 1947. *In that such bulletins are revised from time to time it is possible that a few entries require adjustment to become current.* As some items were expressed in slightly different terms in the various bulletins they were recomputed and reexpressed in the terminology of the Joint Committee report to permit comparison on a uniform basis.

State Recommendations 1946-1947

House Sewers

In Table 13 is presented information contained in State recommendations concerning house sewers. In general a tight sewer of adequate size with sufficient grade to prevent stagnation is recommended. The minimum diameter pipe used is 4 inches with several States requiring the use of 6-inch pipe. Fifteen States recommend the use of cast iron pipe when the sewer is in the proximity of a well. The distance within which this type of pipe must be used varies from 25 to 100 feet from the well, with the usual practice being 50 feet.

Minimum grades recommended vary from 0.5 to 2.0 feet per 100 feet. The most common practice is to use a grade of 1 percent. Recommendations concerning approved jointing materials vary quite widely, however, in ordinary circumstances most States allow the use of mortared joints. Several States call particular attention to the protection of joints to entrance by roots.

TABLE 13.--*Summary of State Health Department Recommendations for House Sewers*

Number	State	Minimum Diameter	Minimum Grade feet/100 feet	¹ Type	² Joints	Remarks
1	Alabama	4 inches	0.5	VC, O	C	CI within 50 feet of W. S.
2	Arizona					
3	Arkansas	4 inches	1.0	VC, O	C, O	6" CI within 100 feet of W.S. A good root-tight sewer
4	California		1.0			
5	Colorado	4 inches	--	VC		
6	Connecticut	4 inches	1.0			
7	Delaware	4 inches		CI, VC		
8	Florida	4 inches	0.5	CI	L	
9	Georgia	4 inches	1.5	VC	O	CI in filled ground or other condition
10	Idaho	Adequate	1.0	VC, CO, CI		
11	Illinois	4 inches	2.0	VC	C	
12	Indiana	6 inches	2.0	VC	C, O	CI within 50 feet of wells
13	Iowa	4 inches	1.0	VC	C, O	CI within 50 feet of wells
14	Kansas	4 in. CI	1.0			
		6 in. VC				
15	Kentucky	4 inches		VC	C	
16	Louisiana	4 inches		CI, VC, O	B, C	
17	Maine					
18	Maryland	5 inches	0.65	VC, CI	C, L	
19	Massachusetts ³					
20	Michigan	4 inches	1.0	VC	C, B	CI within 50 feet of wells
21	Minnesota	4 in. CI	2.0	VC, CI, O	C, L	
		6 in. VC	1.0			
22	Mississippi					CI in loose, fissured and limestone areas. CI within 50 feet of well
23	Missouri	6 inches	1.0	VC	B, C	CI within 50 feet of wells
24	Montana					
25	Nebraska					
26	Nevada					
27	New Hampshire		1.3			
28	New Jersey					
29	New Mexico					
30	New York	6 inches	1.0	VC	BC	CI within 100 feet of wells CI within 50 feet of wells
31	North Carolina					
32	North Dakota	4 in. CI	2.0	VC, CI	C, L	CI within 50 feet of well and in loose, fissured, limestone, lignite and scoria
		6 in. VC	1.0			

TABLE 13.--Cont.

Number	State	Minimum Diameter	Minimum Grade feet/100 feet	Type ¹	Joints ²	Remarks
33	Ohio	4 inches	1.0	CI	L	
34	Oklahoma	6 inches	1.0	VC	C	
35	Oregon	4 inches	2.0	CI, VC, CA, BF, O	L, C, B	
36	Pennsylvania	6 inches		VC	C	
37	Rhode Island					
38	South Carolina	4 inches	2.0	CI, VC		
39	South Dakota	6 inches	1.0	VC	B, C	CI within 50 feet of wells
40	Tennessee					
41	Texas	4 inches		VC		
42	Utah		2.0	VC	C, B	
43	Vermont	6 inches	0.7	VC	C, B	CI within 100 feet of wells (Minimum size, 4 inches)
44	Virginia	4 inches	1.7	VC, CO	C	CI within 50 feet of wells
45	Washington					CI within 50 feet of wells
46	West Virginia	6 inches	1.0	VC	C	CI within 100 feet of wells. Suggest sulphur base comp. and copper rings to prevent root entrance
47	Wisconsin			VC, CI		CI within 25 feet of wells
48	Wyoming					

¹Type

CO = Concrete
VC = Vitrified Clay
CI = Cast Iron
CA = Cement Asbestos
BF = Bituminized Fiber
O = Other Approved Material

²Joints

C = Cement
L = Lead
B = Bituminous
OO = Other Approved Material

³The Massachusetts Department of Public Health advises that it, "...has no authority to regulate, that it does not believe in setting up standards, that each problem must be studied by itself, that the Department does give advice in the matter of such disposal generally in accordance with the 1946 Handbook of the U. S. Department of Agriculture and that all plans of sewerage and sewage disposal in Massachusetts are subject to approval by the Department of Public Health."

Septic Tanks

All State recommendations reviewed favored a rectangular shaped septic tank, and only two States gave design recommendations for round tanks. Six States recommend the use of a two compartment tank, one, the use of three compartments. All others recommend a single chamber tank. Four States recommend that the bottom of the tank should slope toward the inlet end, and another makes the use of a sloping bottom optional. The amount of slope varies from 12 inches to 20 inches in the length of the tank.

The variance in minimum installation is quite great, with very few instances where two or more States agree in all items of design. The average of all factors considered tends toward a 500 gallon (minimum), single-chambered, rectangular septic tank with the length two to three times the width, a water depth of 4 feet, a freeboard of 12 inches, and either tees or baffled inlet and outlet arrangements. The venting of the tank is usually through the main building stack. The design recommendations for the individual States are presented in Table 14.

Capacity and Detention.--Recommendations which state a minimum detention period, favor 24 hours, though they vary from 12 hours to 72 hours. Only about one-fourth of the States specify a minimum detention period, but all of them specify either a definite minimum capacity or minimum dimensions. Of 47 States which furnished information 34, or 72 per cent, favored a minimum capacity of 500 gallons or more (1,000 gallons in one State); 8 States, 17 per cent, a minimum between 400 and 500 gallons; and the remaining 5 States, 11 per cent, indicated minimums of 300 to 400 gallons.

TABLE 14.--Summary of State Health Department Recommendations for Septic Tanks

Number	State	Minimum						Inlet arrange- ment	Outlet arrangement
		Capacity gallons	Detention hours	Depth feet	Free- board inches	Width feet	Length feet		
1	Alabama	500		3.2	12	3	7	El	Tee
2	Arizona	1000		5		3	9	Baffle	Baffle
3	Arkansas	500	18	4	18	--	2W to 3W ¹	Tee	Tee
4	California	810		4	12	3	9	Baffle	Tee or Baffle
5	Colorado	500		4	12	4	7.5	Baffle	Tee
6	Connecticut	500		3.75	18	--	2W ¹	Tee	El
7	Delaware	375		4	12	--	2W ¹	Baffled El	Baffled El
8	Florida	500	24	4	8	--	2-3W ¹	Tee	Tee
9	Georgia	540		4	12	--	2W ¹	Tee	Tee
10	Idaho	500		4	12			Tee	Tee
11	Illinois	500		4	14	3	6	Baffle	Baffle
12	Indiana	500		4	18	3	5.5	Baffle	Baffle
13	Iowa	350		4.5	15	2.25	5.5	Baffle	Baffle
14	Kansas	540		4	12	3	6	Tee or Baffle	Tee or Baffle
15	Kentucky	500		3.2	14	4	6	El	El
16	Louisiana	500	72	4	12	2.75	6.1	Tee or Baffle	Tee or Baffle
17	Maine	400		3	8	4	4.5	Tee	Tee
18	Maryland	735	12	4	12		1-5W ¹	Tee, El, Baffle	Tee, El, Baffle
19	Massachusetts	See footnote, Table 13.							
20	Michigan	500		4.5	6	3	5	None	Tee
21	Minnesota	500		5		3	6	Baffle	Baffle
22	Mississippi								
23	Missouri	485		4	12	3	5	U-bend	Baffle
24	Montana	420		4		2.5	5	Baffle	1/4 Bend
25	Nebraska								
26	Nevada								
27	New Hampshire	500	24	4		3	6	Tee	Tee
28	New Jersey	720		4	18	4	6	Tee	Tee
29	New Mexico	630		4	9	3	7	None	Comb. Y and 1/8 bend
30	New York ²	300 ²	24					Tee or Baffle	Tee or Baffle
31	North Carolina	630		4	9	3	7	None	Comb. Y and 1/8 bend
32	North Dakota	500						Baffle	Baffle
33	Ohio	500		5		3	6	Tee or Baffle	Tee or Baffle
34	Oklahoma	500		4	12	3	6	Tee and Baffle	Tee
35	Oregon	500		4	12	3	6	El	Tee
36	Pennsylvania	420		4.5	24	2.5	5	Baffle	Baffle
37	Rhode Island								
38	South Carolina	500	24	4	12	--	2-3W ¹	Tee	Tee
39	South Dakota	487		4	12	3	5	El	El
40	Tennessee	450		4	12	3	5	El	El
41	Texas	300	24	3.5	12	2.5	5	Tee	Tee
42	Utah	500	24	4	12	3	6	Baffle	Tee
43	Vermont	500	24	4	12	3	6	Tee or Baffle	Tee or Baffle
44	Virginia	450		4	12	2.5	6	Tee	Tee
45	Washington	810		4	9	3	9	Baffle	Comb. Y and 1/8 bend

TABLE 14.--Cont.

Number	State	Minimum						Inlet arrangement	Outlet arrangement
		Capacity gallons	Detention hours	Depth feet	Free-board inches	Width feet	Length feet		
46	West Virginia	500	24	4.5	12	--	2-3W ¹	Tee or Baffle	Tee or Baffle
47	Wisconsin	375	24	4			2W ¹	Tee	Tee
48	Wyoming	480	24	4	12	3	5	El	Baffle
FHA Master Form		500	--	4	12	--	2-3W ¹	Tee or Baffle	Tee or Baffle
	J.C.	500	--	4	12	3	6	Tee or Baffle	Tee or Baffle

¹Width²From Bulletin 26 (1933); N. Y. using FHA standards pending revision Bulletin 26.

Most States favor a ratio of width to length between 1:2 and 1:3. No State recommends a length greater than three times the width. The lowest ratio is 1:1.15. The greatest water depth specified is 5 feet, while the shallowest is 3 feet. Of 46 States reporting, 41, or 89 per cent, recommend 4 feet, or more.

All States allow an air space or freeboard above the tank contents of 12 inches, but these specifications vary from 6 to 24 inches.

With few exceptions, the States recommend that the inlet and outlet to septic tanks be submerged or baffled. Four states recommend no inlet baffling or submergence. As previously mentioned, one of these, the Michigan State Health Department, adopted this design following experimental observation. Most States make the use of either tees or baffles optional for the inlet and outlet structures. Some States specify the use of elbows, U-bends, or a combination Y and 1/8 bend.

Vents.--Most regulations provide for the removal of gases in the septic tank through the main building venting system and through the subsurface disposal system. One State specifies the use of an elbow when there is no trap in the building plumbing. In other cases, elbows, or tees extended above the top of the tank, are to have chipped vents, so that the gases may escape through the building stack or the subsurface disposal system.

Subsurface Disposal System

Location.--All States recommend that a septic tank system be located so that the danger of contaminating a water supply is reduced to a minimum. In general, the recommendations state that the system should be located on ground sloping away from a well and at a lower elevation. The recommendations for individual States are presented in Table 15.

TABLE 15.--Summary of State Health Department Recommendations

Tile Field, Minimum Distances								
Any Water Supply								
50 feet			100 feet			200 feet	250 feet	
Conn.	La.	N.M.	Va.	Ark.	Mont.	Utah	Colo.	Calif.
Del.	Md. ¹	N.C.	Wash.	Iowa	Okla.	Vt.		
Fla.	Mich.	N.D.	(FHA) ²	Ky.	Ore.	Wyo.		
Ind.	Minn.	S.C.		Maine	Texas	(Jt. C.) ³		
Kans.	Mo.	S.D.						

TABLE 15.--Summary of State Health Department Recommendations--Cont.

<u>Streams</u>					
25 feet		50 feet		60 feet	100 feet
Ind.	Vt.	Col.	N.D.	Maine	Ark.
Iowa	Jt. C.	Minn.	Texas		
Oreg.	(FHA)	Mont.			
<u>Dwellings</u>					
3 feet		10 feet		15 feet	25 feet
Fla.		Ore. (Jt. C.)		Ky.	Calif. Minn.
		S.C. (FHA)			Ind. N.D.
<u>Large Trees</u>					
10 feet					
(FHA)					
<u>Property Lines</u>					
5 feet		10 feet		25 feet	
Ind.		(FHA)		Calif.	

¹Does not apply to public water supply in Md. (Greater distances required.)

²FHA - Master Draft.

³Jt. C. - Recommendations of Joint Committee on Rural Sanitation, 1947 Rev.

Most States indicate minimum distances between septic tank systems and any water supply. These distances range from 50 to 250 feet. Seventeen States specify 50 feet while 11 recommend 100 feet.

In eleven States, recommendations are given for the distance to a stream from a septic tank system. These vary from 25 to 100 feet.

Eight States indicate distances varying between 3 and 25 feet between the system and a dwelling. Two States make recommendations for intervening distances between property lines and a septic tank system. These are 5 feet and 25 feet.

Absorption Field Design.--In Table 16 is presented the individual State design recommendations for tile size, grades, joint spacing, distance between lines, depth of cover and other trench details, and in Table 17 following it, a summary of these details.

TABLE 16.--Summary of State Health Department Tile and Trench Recommendations

Number	State	Minimum number lines per field	Minimum length of individual lines, feet	Minimum width of trench, inches	Maximum depth of cover, inches	Preferred depth of cover, inches	Maximum grade, inches/100 feet	Preferred grade, inches/100 feet	Trench spacing (c. to c.) feet	Minimum material under tile, inches	Minimum material over tile, inches	Diameter, inches	Joint opening, inches
1	Alabama	2	75				2	2		6		4	Open
2	Arizona												
3	Arkansas		125	18	36	18	6	6	8	8	1	4-6	1/4
4	California		100	24	30	24	4	4	6	8	2	--	1/4 1/2
5	Colorado			24			1		5	10		4	1/4
6	Connecticut			12		15-18	4	2-4	3-TW ¹	1-2	1-2	4-6	1/4 1/2
7	Delaware			10		15-18	12 1/2	6		9	4	--	Open
8	Florida		100	18	24	18		2-4	3	4	0	4	1/4
9	Georgia			12	30		3		10	4	2	4	Open
10	Idaho											4	1/4
11	Illinois		200				6		10			4	Open
12	Indiana			12					10	4	4	--	Open
13	Iowa		75		30	18-24		4-6	8	6	0	4	1/4
14	Kansas			24		15		2-3		6	Cover	4	1/8
15	Kentucky						4		6	6	6	4	Open
16	Louisiana			18		18		2-3	4-8	6	Cover	4	1/4
17	Maine				24		2		10			4	Open
18	Maryland			15	20		6			2-3	2-3	4	1/4
19	Massachusetts	See footnote, Table 13.											
20	Michigan			18	20	10-12	2			4	Cover	4	1/8
21	Minnesota		100	18				6	3-6	Under	Cover	4	1/4
22	Mississippi												
23	Missouri	2		24				2-3	8-10			4	1/4
24	Montana		100		20	12		2-4	8-10	Under		4	1/4
25	Nebraska									6	3	3-4	1/4
26	Nevada												
27	New Hampshire		100		30	18-30	6	2-3		Under	Cover	4	1/4
28	New Jersey				22			3-6	6	12	4	3-4	1/4 1/2
29	New Mexico			18			2 1/2		10	6	Cover	4	Open
30	New York			12	30		6		4-9	2	4	4	1/8 1/4
31	North Carolina			18	24		2 1/2		10	6	Cover	4	Open
32	North Dakota		100	18		36-60		6	8	Under	Cover	4	1/4
33	Ohio	2	100			18	6	2-4	6			4	1/4 1/2
34	Oklahoma		100	18	24	18	2		10	2	2	4	1/4
35	Oregon		100	18	36		6			6	Cover	4	1/4
36	Pennsylvania		70					2-4				3-4	1/4
37	Rhode Island												
38	South Carolina		100	18			4		8	6-12	3-6	4	Open
39	South Dakota				36			2-3	8-10			4-6	1/4
40	Tennessee			24		12	6		8	4	4	4	Open
41	Texas		50		24	18		1	8				
42	Utah		75	24	30			2-4	6	4	2	4	1/4
43	Vermont	2	100	18	24	18	4		6	6	2	4	1/2
44	Virginia			24	18	12	4	2	6	6	Cover	4	Open
45	Washington			18	24			5	6	6	Cover	4	Open
46	West Virginia		100	12			4	2	6	6	Cover	4	Open
47	Wisconsin							3	4	Under	Cover		1/4 1/2
48	Wyoming							2	10	20	0	4	Open
-	FHA	2	100	18	36	18	6	2-4	--	6	2	4	1/4 Open

¹Trench width

TABLE 17.--Summary of State Design Data--Tile Lines, Trenches

Item	Number of States using recommendations	Maximum	Minimum	Average ¹
(1)	(2)	(3)	(4)	(5)
Minimum number lines per field	3	2	2	2
Maximum length of lines, feet	19	200	50	100
Minimum trench width, inches	27	24	10	18
Maximum depth of cover, inches	21	36	18	24
Preferred depth of cover, inches	18	60	10	18
Maximum grade, inches/100 feet	24	12½	1	4
Preferred grade, inches/100 feet	25	6	1	2-4
Trench spacing, feet	33	10	3	8
Minimum material under tile, inches	35	20	²	6
Minimum material over tile, inches	32	6	0	1

¹This is not a numerical average but approximately represents average conditions²Under tile, no indicated depth

On length of tile for a particular system, others express it in feet of tile per person, or square feet of absorptive area per person, or per bedroom. In preparing Table 18 an attempt has been made to fit the State data into certain common expressions. It was necessary to make some assumptions where basic design data was lacking, but in general the tabulation is of information directly from these bulletins.

TABLE 18.--Summary of State Design Data--Absorption Systems in Various Soils

Item	Unit	Number States	Maximum	Minimum
(1)	(2)	(3)	(4)	(5)
Minimum tile length:	feet	9	250	75
(Porous soil	feet	14	200	70
Tile length (Medium soil	feet	10	350	100-140
Required (Tight soil	feet	9	500	100
Absorption (Porous soil	square feet	11	400	84
Area (Medium soil	square feet	9	600	150
Required (Tight soil	square feet	8	1,000	150
(Coarse Sand				
(or Gravel	feet/capacity	12	40	12
(Fine Sand or				
(Sandy Loam	feet/capacity	6	70-80	20
Tile length (Sand or Loam				
required (some Clay	feet/capacity	9	75-100	30
(Clay some				
(Sand or Gravel	feet/capacity	6	100	50
(Clay	feet/capacity	6	Unsatisfactory	
(Coarse Sand				
(or Gravel	square feet/capacity	5	30-60	18

TABLE 18.--Summary of State Design Data--Absorption Systems in Various Soils--Cont.

Item		Unit	Number States	Maximum	Minimum
(1)		(2)	(3)	(4)	(5)
Absorption Area Required	(Fine Sand or Sandy Loam	square feet/capacity	4	38-100	30
	(Sand or Loam some Clay	square feet/capacity	5	88-100	45
	(Clay, some Sand or Gravel	square feet/capacity	2	100-200	90-120
	(Clay	square feet/capacity	4	Unsatisfactory	

Percolation Test.--Data pertaining to State Recommendations on the basis of the percolation test have been summarized in Table 19 along with data from other sources. As far as can be determined, the percolation test was proposed by Henry Ryon in 1928 in an unofficial publication of the New York Department of Health. Since then it has been adopted widely, but often with unexplained changes, particularly in the higher ranges.

Seepage Pits

Data available from the States concerning the use of seepage pits as a means of septic tank effluent disposal are given in Table 20. Of 32 States making recommendations concerning seepage pits, only 4 prohibit their use. The others recommend the use of pits of various designs and construction for a variety of conditions. Some States require that the pits be of certain size, while others base the design on the absorption area required as shown by a percolation test. Several require that the pit extend into a porous formation. One State does not approve the use of seepage pits unless tile field systems are not suitable, while several recommend that a pit be used at the end of the tile lines. One state does not allow the use of seepage pits unless the lot area exceeds one-half acre. This is the only case where a minimum size lot is required.

Four States recommend the use of the percolation test for designing seepage pits, and a comparison of these data show that no two are the same, though they are in general agreement. Five States made recommendations as to absorption area required based on the type soil encountered. These, too, show considerable variance between States. Table 21 lists the recommendations.

Twenty States specify certain minimum distances between seepage pits and water supplies, streams, dwellings or property lines. The usual distance from a water supply is 100 feet though the individual recommendations vary from 30 to 300 feet. Other recommendations vary widely, and only a few States present specifications for all conditions listed above.

Cesspools

Table 22 presents the data available from State sources concerning cesspools. Recommendations are given by 19 States, and of these, cesspools are allowed in 12, and prohibited in 7. However, of those States allowing the use of cesspools one requires that they are to be used for floor waste only, another for laundry waste only, and another for kitchen and laundry only. Practically all of the States allowing their use qualify the requirements, and, in general, the use of a cesspool is not recommended as the desirable system of sewage disposal. In some States where the use of cesspools is prohibited, the Codes governing disposal facilities specifically state that cesspools shall not be used.

TABLE 19.--Various Absorption Line Recommendations on Basis of Percolation Test
Square feet (trench bottom) per Bedroom

	Time for water to fall 1 inch													
	Seconds					Minutes								
	10	15	30	45	1	2	3	4	5	10	15	30	45	60
1. Ryon report, 1928	30	32	34	36	40	50	58	66	72	96	120	190	260	330
2. Jt. Comm. 1947 Rev.						50	60	70	80	100	130	180		240
3. FHA Master Form, 8/1/46						50	60	70	80	100	120	180		240
4. Connecticut						34	40	46	50	66	80	126	174	220
5. Idaho						52	60	72	80	105	126	180		240
6. Kansas										120-	160-	200-		280-
										160	200	280		400
7. Louisiana						52	60	72	80	104	126	180		240
8. Maryland					36	45			60	90		180		240
9. Missouri	30	32	34	36	40	50	58	66	72	96	120	190	260	330
10. New York					20-	25-			33-	47-		100-		134-
					30	37			50	71		150		200
11. Ohio						52	60	72	80	105	126	180		240
12. Oklahoma	45	48	51	54	60	75	87	99	108	144	180	285	390	495
13. Oregon						50	50		80	100	125	175		250
14. South Dakota	30	32	34	36	40	50	58	66	72	96	120	190	260	330
15. Texas					36	45			60	90		180		240
16. Vermont						52	60		80	104	126	180		240
17. West Virginia					24	30			40	60		120		
18. Berry, SWJ 3/44					29	33			50	67		143		200
19. Flood, SWJ 1/44					25	31			42	59		125		167

TABLE 20.--Seepage Pits--Summary of State Regulations--Location--Feet

Number	State	Approved	Any Water Supply	Streams	Dwellings	Property Lines	Remarks
1	Ala.	No					
3	Ark.	Yes	100	100			Pit recommended at end of tile line or filter.
4	Calif.	Yes	250		25	25	Install tile field and/or seepage pit depending on soil, water table, wells and lot space.
5	Colo.	Yes	300	100			
6	Conn.	Yes	50				Allow 3 feet diameter space between pits.
7	Dela.	Yes					Open joint, stone or brick.
8	Fla.	No					"Sumps, dry wells, soakage pits or drain wells shall not be used for disposal of septic tank effluent."
10	Idaho	Yes	100		20	10	"Not necessary with cesspools." No pits to be dug into water table.
11	Ill.	Yes	100				Allowed with or without tile field; lined with brick or stone.
12	Ind.	Yes	75	25	50	5	Not approved unless tile fields fail or public water supply is used; disapproved near shallow wells. Inadvisable as means of septic tank effluent disposal.
16	La.	Yes	50				
17	Maine	Yes	100	60			
18	Md.	Yes	50 ¹				For septic tank effluent. Brick lined absorption area to exclude bottom. Not used in shallow well areas.
20	Mich.	Yes	50				Health department approval required. Should extend to porous soil.
21	Minn.	Yes					Use of abandoned well, cesspool, sinkhole, etc., not allowed. Pits to be at least 10 feet above water table.
23	Mo.	Yes					"Tilefields are more satisfactory than leaching cesspools."
25	Nebr.	No					"Inno case is it advisable to use a leaching well or cesspool," for an absorption field.
27	N. H.	Yes	100	75			Not suitable if water table within 8 feet of surface; bottom at least 2 feet above water table, good flow = 30 gallons.

TABLE 20.--Seepage Pits--Summary of State Regulations--Location--Feet--Cont.

Number	State	Approved	Any Water Supply	Streams	Dwellings	Property Lines	Remarks
29	N. M.	Yes	50				"A pit at least 3 feet in diameter by 1 to 3 feet deep should be dug at the end of the tile line." Filled with cinders.
30	N. Y.	Yes	100				For daily p.c. flow = 50 gallons. Excludes bottom area. Not suitable if water table is less than 8 feet deep.
31	N. C.	Yes	50				Should be dug at end of tile line.
32	N. D.	Yes	50				If possible situate at least 10 feet above water table, can be used in favorable soils without tile field.
33	Ohio	Yes	100				Not for less than one-half acre lots. Sides and bottom in sand or gravel above water table.
35	Oreg.	Yes	150	25	10	10	Health department approval required. Not used in limestone or shallow well areas. For daily p.c. flow = 50 gallons.
39	S. D.	Yes					Operate satisfactorily in relatively porous soil.
42	Utah	No					
43	Vt.	Yes	100		20		Allowed "under favorable ground conditions." 1 foot of gravel on bottom--bottom 2 feet above water table.
45	Wash.	Yes					"A pit---should be dug at the end of the tile line." Filled to surface with cinders.
46	W. Va.	Yes	100				Consult health department installed at end of tile not lined.
47	Wisc.	Yes	150		50		
48	Wyo.	Yes					Use after septic tank or at end of tile line.

¹Does not apply to public water supply in Maryland (greater distances required).

TABLE 21.--Seepage Pits--Summary of State Recommendations--Absorption Area

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Percolation Test, square feet/bedroom										Square feet/bedroom					
Minutes										Coarse sand or gravel	Fine sand or sandy Loam	Sand or loam, some clay	Clay, some sand or gravel	Clay	
1	2	3	4	5	10	15	30	45	60						
6. Connecticut:															
	34	40	46	50	66	80	126	174	220	39	64	128			
10. Idaho															
	--	--	--	--	--	--	--	--	--	20	30	50	80-160	US ¹	
18. Maryland:															
31	39	--	--	47	71	--	102	--	US ¹						
27. New Hampshire:															
20	24	--	--	34	46	--	100	US ¹	--	6	9	15	24	US ¹	
30. New York:															
32	40	--	--	56	76	--	160	US ¹	--	20	30	44	US ¹		
35. Oregon:															
	--	--	--	--	--	--	--	--	--	20	30	50	80-60	US ¹	

¹US--Unavailable

TABLE 22.--Cesspools--Summary of State Requirements

Number	State	Approved	Remarks
1	Alabama	No	"Cesspools, leaching pools and the like are strongly disapproved---."
2	Arizona	--	
3	Arkansas	--	
4	California	Yes	Ground water should be 15 feet to 20 feet below the surface, if used.
5	Colorado	--	
6	Connecticut	Yes	No cesspools within 50 feet of a water supply stream. Recommend septic tanks.
7	Delaware	--	
8	Florida	--	
9	Georgia	--	
10	Idaho	Yes	Acceptable only in certain areas; not allowed in shallow well areas--minimum capacity 1,000 gallons 3 feet diameter.

TABLE 22.--Cesspools--Summary of State Requirements--Cont.

Number	State	Approved	Remarks
11	Illinois	No	
12	Indiana	No	
13	Iowa	Yes	Allowed for kitchen and laundry wastes. No statement re sewage. Maximum depth 12 feet 1-1/2 to 3 c.y. cap. (crushed stone fill).
14	Kansas	No	Cesspools have been condemned, also the use of abandoned wells.
15	Kentucky	--	
16	Louisiana	Yes	Local health department approval required. Not to be used where ground water supply will be contaminated.
17	Maine	Yes	Health department approval required. Not allowed if water table is less than 4 feet deep. Use of abandoned wells not allowed.
18	Maryland	--	
19	Massachusetts	--	
20	Michigan	No	
21	Minnesota	No	"A cesspool is not recommended as a substitute for a settling tank."
22	Mississippi	--	
23	Missouri	--	
24	Montana	--	
25	Nebraska	--	
26	Nevada	--	
27	New Hampshire	--	
28	New Jersey	Yes	5 feet--10 feet diameter and 7 feet--12 feet deep; brick or stone lined. Not allowed around shallow wells.
29	New Mexico	--	
30	New York	Yes	Preferably follow a septic tank (seepage pit), or, built in 2 units, 6 foot diameter; bottom above water table. Stone, brick or building tile lining.
31	North Carolina	--	
32	North Dakota	No	
33	Ohio	No	
34	Oklahoma	--	Apparently not allowed.

TABLE 22.--Cesspools--Summary of State Requirements--Cont.

Number	State	Approved	Remarks
35	Oregon	Yes	Local health department approval required--4 foot minimum diameter and 15 feet below inlet, penetrate 5 feet into porous material--location same as seepage pits.
36	Pennsylvania	--	
37	Rhode Island	--	
38	South Carolina	--	
39	South Dakota	--	
40	Tennessee	--	
41	Texas	--	
42	Utah	Yes	For disposing of floor waste only. Only a temporary expedient for sewage. 5 foot diameter lined with cobble stone and above water table.
43	Vermont	Yes	For laundry wastes. Not recommended for sewage.
44	Virginia	--	
45	Washington	--	
46	West Virginia	--	
47	Wisconsin	No	Cesspools are contrary to the Code.
48	Wyoming	--	

*Design Practice Outside the United States**Canada*

The design of septic tank systems of sewage disposal in Canada was described by Berry (581) in 1944. A detention period of 24 hours is recommended using a per capita flow of 50 gallons and an allowance for two years sludge storage at a rate of 1 to 20 gallons per person per year. Berry suggests that the minimum size tank be between 300 and 500 gallons. Tees or baffles are required at the inlet and outlet of all tanks. Perry questions the necessity for using a dosing siphon in small installations, but states that if one is used the dose should be sufficient to fill the tile lines about three-quarters full.

The subsurface disposal field should be constructed of 4 inch drain tiles laid with 1/2 inch openings on a grade of 4 to 6 inches per 100 feet. The use of stone or gravel around the joints is preferred to tar paper covering. The tile should be laid in rows of equal length spaced 4 to 5 feet apart, or at least three times the trench width. Better results are to be obtained if the tiles are laid 18 to 30 inches below the ground surface. Berry suggests the use of a percolation test to determine the length of tile required. A 1 foot square hole is used and 6 inches of water allowed to seep away. Trench area requirements can then be obtained from this table.

Time for water to
fall 1 inch

Sewage loading per square feet
of trench per day

minutes

gallons

1	3.5
2	3.0
5	2.0
10	1.5
30	0.7
60	0.5

England

A brief resume of English design practice was given by Ferguson (597) in the *Surveyor* in 1945. The author states the great need for fundamental research in the design of sewage treatment facilities for isolated houses, and the need for some standardization in design practices. From his remarks it may be assumed that many varied designs are used.

Ferguson recommends the use of a long narrow tank with a maximum width of 2 feet and a length of 6 feet 6 inches or more to obviate stagnation and over-septization and too quick movement through the tank. He mentions the use of a factor of 2 cubic feet per capita for designing a tank except in the case of very small units, and also states that it has been suggested that the width of the tank in feet should be one-fifth of the square root of the maximum number of users. For a minimum installations, the author recommends a tank 6 feet long by 2 feet wide by 4 feet water depth with a hanging baffle two-thirds of the length of the tank from the inlet end. There should be a clear space of 18 inches between the bottom of the baffle and the bottom of the tank. Ferguson states that the inlet and outlet devices should be made of drainage branches taken at least 6 inches below the water surface, with ventilation provided at the inlet.

No mention is made of methods for the disposal of the septic tank effluent.

India

The design of septic tanks for the use in India was described by Temple (506), (507) and Ganguli (534). Both authors mention experimental work of Colonel Clemensha and Chakravarti as well as experimental observations each has made. However, no references are made to any published reports, nor are any factual data cited in these papers.

Temple's article surveys the problem of sewage disposal in rural communities, and in general treats of plants for more than one household. He states that the experimental work of Clemensha developed a tank with a capacity of 2 cubic feet per capita based on 5-40 gallons of sewage per capita. The depth should be 6 feet and the ratio of length to width, 7 to 1. In the discussion of Temple's paper it was brought out that these dimensions do not apply for small populations. Clemensha's tank has two compartments, the first one-eighth of the tank, with a hanging scum board in the first chamber. It is claimed that this baffle greatly improves operation. The inlet and outlet were submerged to a depth of 2 feet 6 inches below water level.

Temple's work indicated that this design was satisfactory, but that the capacity could be reduced to 1.7 cubic feet per person by using chlorine and frequent sludge removal. The use of a "lamus arrester" or upward-flow filter of 2 inch coarse material is recommended before application of the tank effluent to a filter and frequently before discharge to land.

The paper also describes Chakravarti's tank which is a two compartment rectangular tank with submerged inlet and outlet. The capacity per user varies from 3.75 cubic feet for a 10-person tank to 2.21 cubic feet for a 300-person tank. For the smallest tank the

dimensions are 6 feet by 2 feet, 6 inches by 2 feet, 6 inches water depth. It is stated that these tanks worked well and with little or no attention.

Ganguli recommends the use of 2-1/2 cubic feet per person for designing the septic tank, though he states 2 cubic feet is a fair allowance. His other design factors are similar to those used by Clemensha. Ganguli estimates that the space required for sludge storage is one-half cubic foot per person per year. Various tank designs are given in this paper and include some based on Clemensha's and Chakraverti's experiments, and round tanks advocated by Temple. Temple's tanks for small populations have submerged inlet and outlet, a vertical baffle in the center of the tank, and a water depth of 6 feet. For populations of 5, 10 and 20 persons the tank diameters are 1 foot, 9 inches, 2 feet, 3 inches and 3 feet, respectively. A single chamber tank is shown, but Ganguli states that this design has not been successfully used. Ganguli recommends that a small amount of sludge be left for seed when a tank is cleaned.

Australia

Regulations for the construction of septic tanks in Victoria, Australia were reported by Hepburn (461) in 1936, and were based on the investigations mentioned in the research section of this report. These rules are:

1. Capacity: $300 + 30 N$ gallons (Imperial) or more, where N is the number of persons.
2. Depth: Not less than 3 feet, 6 inches for tanks up to 600 gallons capacity, and proportionately more for larger tanks.
3. A single-chamber tank or the first chamber of a multi-chamber tank to have its length at least three times its width.
4. Tanks of complicated design will not be accepted, and no allowance will be made for chambers filled or partly filled with stone, coke, etc. Subdivision into a large first and a small second chamber is preferred for all tanks 8 feet or more in length.

These rules are applicable to tanks treating only water closet and urinal wastes. For treating all household wastes, the author states that a tank capacity of $400 + 30 N$ Imperial gallons will not prove excessive.

New Zealand

In 1938 the Journal of Agriculture of New Zealand (488) recommended a septic tank system to treat all household wastes. A three-compartment concrete, brick, or cement-faced stone tank was proposed. The length recommended was 7 feet, the width 2 feet, and the water depth 2 feet, 6 inches. Both the inlet and outlet were tees with the entrance to the second chamber through six 4 inch by 5 inch parts, and the entrance to the third compartment through two sloping pipes. The tank was vented through the inlet tee to the ground surface, and a distribution box was cast as an integral part of the tank structure. Either 3 inch or 4 inch drain pipe was recommended for the tile field with the trench 18 inches wide and 27 inches deep. No data were given as to the length of tile required nor were any design factors given for the tank described.

South Africa

Burt (389) reported in 1933 on a septic tank to treat all household wastes, and Oosthuizen (601) in 1945 on a tank to treat only water closet wastes. The tank proposed by Oosthuizen is considerably larger than that recommended earlier by Burt, and though no flow data are given it may be assumed that Oosthuizen's tank provides a much longer detention period, since it treats only water closet wastes.

The following recommendations are made by Burt.

Tank Sizes

Persons	Capacity U.S. gallons	Length feet	Width feet, inches	Depth feet	Water Depth feet
to 6	281	5	2-6	4	3
8	405	6	3	4	3
10	473	7	3	4	3
12	540	8	3	4	3
14	630	8	3-6	4	3

Computed

A single chamber tank may be built, but the use of a dosing siphon is recommended. The tank should be cleaned every three or four years. Burt recommended that the tile field be constructed of 3 inch diameter agricultural drain pipes laid on a grade of 4 inches to 6 inches per 100 feet with 1/8 inch openings between tiles and a maximum cover of 18 inches. No recommendations are given for the length of tile or absorption area required.

Oosthuizen recommended that only water closet wastes enter the septic tank, and that bath water and kitchen wastes be discharged to a trench drain (leaching cesspool filled with stones). The tank should be 50 feet to 100 feet away from the building and the drain at least 30 feet. The tank recommended for treating the wastes from 5 persons or less has a capacity of 450 U. S. gallons and is 5 feet long, 3 feet wide, and a water depth of 39 inches at the outlet and with the bottom sloping to 57 inches at the inlet end. The inlet is through a tee, with a plate perpendicular to the tee 4 inches below the end to prevent disturbance of the tank by a sudden inrush of sewage. The outlet is a weir with a sloping scum board in front. No information is given concerning the disposal of the septic tank effluent.

Rhodesia

Writing in the *Rhodesia Agriculture Journal*, Haviland (434) recommends the following system. The tank should provide a minimum detention period of 48 hours based on a flow of 35 gallons per capita per day. However, the assumption of 80 gallons per capita is used in designing the tank. A single compartment tank for four persons should have the following dimensions:

Length 4 feet	Water depth . 4 feet
Width 3 feet, 6 inches	Freeboard.... 18 inches

The inlet should be provided with a tee and the outlet baffled. A two compartment tank should have these dimensions:

Length, 1st 4 feet, 9 inches	Width 3 feet
Length, 2nd 2 feet	Water depth . 4 feet
	Freeboard ... 18 inches

All inlets and outlets are to be provided with tees except the inlet to the second chamber, which has no tee or baffle.

The tile disposal field for this system should be at least 200 feet from wells, and a minimum of 12 inches above the ground water level. The first half of the system may be 4 inch tile, and the second half 3 inch tile. The open joints should be covered with galvanized iron sheets, and there should be 3 inches of gravel or cinders over and a small amount under the tile. The preferred depth of cover is 18 inches and the tile should be laid on a grade of 3 inches per 100 feet. In dry, porous, well drained sandy soil about 200 square feet of land will be required per person and about 400 square feet in a heavy loam. In sandy soils the distribution pipes should be laid 15 feet apart, and in heavy soils about 8 feet to 10 feet apart. A subsurface filter should be used in clay soils.

This section is based on only one reference, and cannot be assumed to represent usual practice in building a septic tank system in this country. Very little information is given as to the length of tile required per person for various soils, the only statement being that concerning the area. The assumed absorptive area is not given, hence the length of tile cannot be computed.

Germany

In recent years general practice in the design of septic tanks in Germany has undergone considerable change. These changes were occasioned by the use of so called "fresh-water clarification tanks," their subsequent descendency, and increased use of the older types of septic tanks. Numerous articles have been reviewed which treat of various types of patented fresh water tanks, most of them being modifications of an Imhoff type tank, and affording detention periods of 1 to 2 hours. Schreiber (399) states that a fresh-water type of tank should be used where the effluent may be discharged to a watercourse, but that the effluent is not suitable for soil absorption. The fresh effluent provides nutriment for micro-organisms which multiply rapidly and soon clog the soil.

For conditions under which soil absorption of the effluent is necessary Schreiber recommends the construction of septic tanks with at least three compartments. In particular he recommends the use of a round tank divided into four parts by a baffle system. Sludge storage is effected by a continuation and enlargement of the first chamber. To use this tank as a fresh water plant, the effluent leaves from the third chamber, and continues into the fourth when used as a septic tank. The first and second chambers serve to remove the heavier materials, and both open into the sludge storage compartment. The other chambers are used to remove finer material.

Imhoff in his book, *Taschenbuch der Stadtentwässerung*, recommends the use of a tank with a capacity of 300 liters per capita if the tank is to be cleaned once a year and the sludge used for fertilizer and a capacity of 1000 liters per capita if the sludge is not used for fertilizer. The inlet should be a free fall to break up the scum and the outlet should be submerged. Baffles are used in the tank, presumably to effect compartmentation. Imhoff states that the tile field should be about 0.5 meters deep and surrounded with broken stones or gravel. At least 15 meters of tile should be provided per capita and two lines provided per capita and two lines provided to allow only one to be used at a time.

Sierp in *Lebensmittel Chemie* recommends the use of a large three-chamber tank to allow a detention period of 12 to 15 days. The design is the same as that used in Poland and noted in a later section of this review. For the minimum size tank the first chamber should have a capacity of 3 cubic meters, the second 1.5 cubic meters, and the third 1.5 cubic meters. Sierp recommends that where possible the primary treatment should be made complete by secondary treatment. Various types of trickling filters are recommended, and the use of subsurface disposal systems with a length of 15 meters per person are given. Sierp states that good absorption of the water can be obtained by providing sufficient aeration of the soil and arranging the tile to make the water available to plants by capillarity. To provide sufficient aeration, he recommends the use of some sort of dosing device. Imhoff recommends the use of a biological filter for soils of poor absorption qualities.

Sierp states that fresh-water tanks should be cleaned twice yearly, and that the large three-compartment tank should be cleaned when the sludge quantity is one-third of the capacity of the first chamber.

Poland

During a recent visit to the United States, A. B. Szniolis of the Polish State Institute of Hygiene described the practices followed in Poland for the design of septic tank sewage disposal systems. In general the design factors are similar to those reported in

Lebensmittel Chemie as representing German practice. In general, the tank capacities are quite large in comparison with American standards. While the minimum detention time is 24 hours, the preferred detention period is 3 to 20 days, and the preferred design capacity 1 cubic meter per capita (264.2 gal.).

Both rectangular and round tanks are built with three chambers. The first chamber is one-half the total capacity, and the second and third each one-fourth the total capacity. The tanks have three compartments to prevent serious disturbances due to the discharge of warm water from bath tubs. This quantity of water varies between 300 and 350 liters (approximately 80 to 92 gallons). The rectangular tank has a minimum depth of 1.5 meters (4.9 ft.) and a preferred depth of 2 meters (6.6 ft.). The length is three times the width. Cast iron tee fittings are used for the inlet and outlet and between compartments, and they are placed diagonally opposite in all chambers. The system is vented through the building plumbing stack and at the end of each tile line. The round septic tanks are constructed of unreinforced precast concrete rings. These rings are usually made 0.85 meter (2.8 ft.), 1 meter (3.2 ft.) or 1.5 meter (4.9 ft.) in diameter. The depth of the first tank is 2 to 3 meters (6.6 to 9.8 ft.) and the second and third is 1.5 meters (4.9 ft.). Both types of tanks should be cleaned when sludge appears in the third compartment.

The length of tile varies from 3 meters (9.8 ft.) to 20 meters (65.6 ft.) per capita depending on the porosity of the soil. The tile is usually placed 1 meter deep in a trench 0.7 meter wide. Crushed stone or gravel is placed under the tile for 6 inches and around it, and the entire field is covered with tar paper 0.7 meter wide. The tile is either 1-meter lengths of bell and spigot concrete pipe or 0.3 inch lengths of clay pipe. The main line is approximately 6 inch diameter pipe and the laterals 4 inch diameter. Distribution boxes are not used. In clay soil, either a trickling filter or 30 minutes contact with a calcium hypochlorite solution is used before discharge to a watercourse.

Szniol is stated that small Imhoff tanks should not be used, and the experience indicated that fresh sewage should not be applied to subsurface tile fields.

According to Skrobecki writing in a recent issue of a Polish journal, the "Oms" type settling tank has found satisfactory use in Poland. This type of tank is a modified Imhoff tank similar to the fresh-water clarification tanks used in Germany during the 1920's. Usually built in round form, the flowing-through chamber is located above the digestion chamber and connected by means of a narrow slot. (See cut in Appendix A).

The settling chamber has a capacity equal to 20-25 percent of the daily wastes with a minimum of 0.5 cubic meter or 147 gallons. The surface area in square meters should be numerically equal to the volumetric capacity in cubic meters. Between 0.07 and 0.1 cubic meter digestion space is provided per person with a minimum of 1 cubic meter (35.3 cu. ft.).

Skrobecki states that cleaning of these tanks should be done every six months, but that in practice it is usually one or two years. The tanks are usually built of precast concrete rings 1.1 meter in diameter.

Venezuela

The health authorities of Venezuela specify a single compartment rectangular tank of sufficient capacity to afford a detention period of 24 hours. The minimum size tank (to serve 1 to 4 persons) has a capacity of 1300 liters and the following dimensions: Length, 1.3 meters; width, 1.0 meter; water depth, 1.0 meter; freeboard, 0.3 meter. The tank is equipped with tee inlet and outlet.

For effluent disposal the use of seepage pits of sufficient capacity is recommended. No specific recommendations are given; however, consideration of the soil permeability and local conditions is advised. The use of seepage pits in areas served by shallow wells is prohibited.

Ecuador

The Direccion General De Sanidad, Republic of Ecuador, recommends the use of a single compartment rectangular septic tank for from 1 to 10 persons. The tank is 1.4 meters long, 0.7 meter wide, and 1.2 meters water depth with a freeboard of 12 inches. It has a tee inlet to 18 inches below the water surface, and a tee outlet to 12 inches below.

For effluent disposal three methods are given; disposal to a river or estuary; filtration through a subsurface tile field; or disposal through a system of seepage pits. The tile field is made up of 4 inch diameter concrete or vetrified clay pipes, 1 foot long, laid with a grade of 3-4 inches per 100 feet. The following amounts of tile are specified: porous soil, 20 meters; medium soil, 30 meters; clayey soil, 50 meters.

No recommendations are given as to the size or capacity of seepage pits, nor is the use of such a system qualified. The use of effluent discharge to a stream is not recommended where contamination of a domestic water supply would result.

Dominican Republic

The septic tank recommended by the health department of the Dominican Republic to serve 10 persons has the following characteristics:

2 compartment rectangular:

Length, 1st	1.3 meters	Width	0.9 meters
Length, 2nd	0.7 meters	Water Depth	0.9 meters
		Freeboard	0.3 meters

The inlet is an elbow and the outlet a tee. No details are available concerning disposal systems.

SECTION B

SURVEY OF CONTROLS AND PRACTICES IN SOME LOCAL HEALTH UNITS

SURVEY OF CONTROLS AND PRACTICES IN SOME LOCAL HEALTH UNITS

As the survey literature, and contacts with various officials, manufacturers and workers concerned with individual household sewage disposal systems, developed during the early part of this Project, it became evident that not only was the technical foundation on design concepts weak, but that control of installation and servicing of such systems was weak also.

While local controls may be thought of as something aside from an attempt to solve some of the many technical design problems which beset this field, it is of importance to consider that the best in design will fall short of its goal through lack of proper installation and servicing.

This is a unique field of sewage treatment as compared to professionalized municipal practice, in that control over servicing, and to a lesser extent, control over the initial installation, are in many cases left to the householder, who usually suffers the consequences of his lack of knowledge in this field. That difficulties on this account are common, and expensive, is indicated by servicemen, who claim that in over 50 per cent of the cases in which they are called upon by householders for servicing, tank cleaning was long overdue, and the tile field filled with sludge as a result.

In an effort to learn something of the general status of local control practices over the country, local health departments, having fulltime health officers, were circularized by mail, on the basis of a uniform questionnaire dealing with a number of items in this connection. The poll was confined to this group because of the ready availability of a national list of such health units, and, on the assumption that, taken as a whole, the bulk of organized information and control in this field would be found in this group. This does not hold in some States where local control lies in part-time health officer units or district arrangements.

The field consisted of 1,247 city, county, city-county, state district and local district health units having full time health officers, in 47 States. Questionnaires were mailed in March, April and May, 1948. The total response to date has been 794 or 64 per cent of the field. Replies ranged from acknowledgment of questionnaire with indication of no control or no information, to the fully executed questionnaire.

The questionnaire used in the poll appears in Appendix B. In transmitting the questionnaire it was explained that the purpose of the survey was to develop the facts on local practices and control as they exist with no intention of utilizing the information to criticize any individual program.

An examination of most of the items on which information was solicited is presented in the paragraphs following. Other items, such as costs, were solicited for use in connection with design considerations and will be covered at a future time.

The estimated number of individual household systems in the areas responding was in excess of 1,950,000, or in terms of population connected, in excess of 7,800,000 persons.

Of 726 health units responding on the question of control, 372 indicate control in the entire local area, 173 in part of the areas under their jurisdiction, 35 control with areal extent unspecified, and 146 report no control. In percentages, these represent 51, 24, 5 and 20 per cent respectively, of the total return on control.

The control agency was indicated as the health department in almost all cases. Of the total response by 610 health units on this point, 551 identified the local control agency as the health department, 22 the plumbing department, 13 plumbing and health departments, and the remaining 24 variously sanitation department, water department, zoning bureau, city engineer's office, city council, health and engineering department, housing or building department, metropolitan district and combinations of the above.

444 health units reported on the date control was initiated. The summary of these is presented in Table 23.

TABLE 23.-- *Progress of Local Control*

Period Control Started	Number Local Health Units Reporting		Cumulative	
	In Period Number	Indicated Per Cent		
Before 1910	11	2	11	2
1910 - 1919	12	3	23	5
1920 - 1929	62	14	85	19
1930 - 1934	33	8	118	27
1935 - 1939	107	24	225	51
1940 - 1944	106	24	331	75
1945 - 1948	113	25	444	100
Total	444	100		

It appears that for the 444 local units reporting control dates controls were adopted prior to 1935 by about one quarter of the group, and are of more recent date for three quarters of the group.

From examination of the documentary material furnished by some of the respondents it appears that the usual ordinance:

- (a) Requires some form of sewage disposal.
- (b) Requires connection to sewerage system where possible.
- (c) Specifies the type of disposal systems (cesspools prohibited in many instances).
- (d) Requires a permit for installation of septic tanks.
- (e) Specifies the size of tank.
- (f) Specifies the length of tile field.
- (g) Requires inspection of area before work is started.
- (h) Requires approval before backfilling.
- (i) Provides for fines and/or imprisonment for failure to comply.

A few ordinances require in addition that installation be made by a licensed contractor or plumber. Still fewer regulate the operation of tank cleaners, in connection with which the items covered, variously, are:

- (a) Licensing of approved scavengers.
- (b) Bonding of scavengers (ranging from \$1,000 to \$5,000).
- (c) The type of vehicle, size and type of tank, and identification on vehicle.
- (d) Permit for each job.
- (e) Time of day, or year, during which tank cleaning is permitted.
- (f) Method of disposal of tank contents, such as burial, open fields for underplowing, municipal sewage treatment plant.
- (g) Violations punishable by fines and revoking of license.

There are also in force, in some instances, the following:

- (a) Disinfection of tank contents before removal (method not indicated).
- (b) Specification of the interval in which tank must be cleaned, generally 3 years.
- (c) Right of way secured for health inspectors, etc.
- (d) Some form of blanket regulation, such as: requiring tanks to be operated without creating a nuisance, denying the use of defective tanks or tanks not operating properly, requiring inspection of tanks at any time by the Board of Health.

On the question of design recommendations, 654 units responding indicated use of local recommendations in 45 cases, state recommendations in 257 instances, and 352 utilized both.

The numbers of household septic tank disposal systems reported in the poll totalled 1,950,000, not all of the units reporting. The number of installations made under control amounted to 710,000 for those units providing figures. Summarizing the numbers of installations in areas reporting both total and controlled installations the comparison is 1,590,000 total installations, as against 640,000, or 40 per cent, installed under control.

The response to inquiry on specific measures having to do with local control and guidance in the installation and maintenance of household systems, is summarized in Table 24.

TABLE 24.-- Summary of Response on Control and Guidance Measures

Item	Total Response	Response Affirmative		Response Negative Number
		Number	Per cent	
Does Control Agency				
(a) Require installation permits	690	328	48	362
(b) Require installation by skilled tradesmen	687	181	26	506
(c) Maintain record of each installation	686	425	62	261
(d) Maintain record of complaints	687	429	63	258
(e) Make preliminary inspection of site	678	533	79	145
(f) Make percolation tests	674	339	50	335
(g) Examine soil	660	363	55	297
(h) Require percolation tests (by others)	672	192	29	480
(i) Require soil samples	676	45	7	631
(j) Specify individual absorption field size	669	513	77	156
(k) Make final inspection before backfill	684	557	82	127
(l) Furnish maintenance instructions to householder	666	232	35	434
(m) Require installer to furnish maintenance instructions	659	53	8	606

Thus it appears from the response summarized in Table 24 that approximately half of the local health units require installation permits, and that installation by skilled tradesmen or services is required by one-fourth of the units responding. In over half the cases, the maintenance of records of installation and complaints, 62 and 63 per cent respectively, is reported.

Items "e" through "k", Table 24, concern installation control measures involving inspectional manpower in the local unit. In connection with these items it was felt that an indication of the percentage of cases to which these measures were applied would be of importance. The summarized response is presented in Table 25.

It is apparent from Table 24, items "l" and "m" that an important local service to the householder, that of providing instructions on servicing septic tank systems, which could be developed at little cost, is lacking in a large number of local units. It might be mentioned in this connection that a number of householders in inspection areas evidenced much interest in their facilities, but had not been aware of servicing responsibilities in connection with their proper operation.

TABLE 25.--Percentage Application of Installation Control Measures

Control Item	Number Local Units Reporting Percentages	Application Per cent of Installations
e. Preliminary inspection	433	65
f. Make percolation tests	256	35
g. Examine soil	257	63
h. Require percolation test	123	50
i. Require soil samples	14	53
j. Specify individual absorption field size .	362	84
k. Final inspection before backfill	369	81

Examining Tables 24 and 25 together, on the control items "e" through "k" previously mentioned, it appears that control weakness is evidenced in the small net percentage of installations receiving the attention listed in items "e" through "h". The low score on item "i. Require soil samples", is of little consequence, as soil composition alone is a very limited guide to percolation quality, soil structure being a much more important factor. The relatively high score on items "j" and "k", dealing with individual tile field size and final inspection, is very encouraging. With improvement in technology the application of these two items should prove highly effective.

Complaints of difficulties received by individual local health departments ranged from zero to 25, or more, per month in each of 18 states, and from zero to less than 25 in the remainder reporting.

Response was invited on the relative frequency of complaints of specific nature, and also on causes of difficulties. Lists of several possible sources of complaint and causes of difficulty were provided in the questionnaire. Approximately 400 health units responded on these, providing at least the first and second designation of order of frequency. The items concerned are listed below, in descending order of frequency:

Nature of Complaint

1. Seepage to ground surface.
2. Odor nuisance.
3. Plumbing fixtures will not drain.
4. Sewage backing into cellar.
5. Other (Grease and sewage appearing in ditches and surface, drainage field inadequate, soil will not absorb, system overloaded, lack of instructions, mosquito breeding and roots, in that order).

Cause of Difficulty

1. Tile field clogged.
2. Tank cleaning overdue.
3. Sewer clogged.
4. Tank inlet clogged, and other (Improper installation, high water level, poor soil, septic tank too small, improper maintenance, system overloaded, improper instructions, improper design and roots, in that order).

Regulation of cleaning services was reported in 172 units, as against no regulation in 500 units, of the total of 672 units responding on this question, indicating control in only 27 per cent of the units. As to type of control, 116 units reported as follows: regulation, 45; local ordinance, 24; permit, 28; license, 15; and individual permits, 4.

Difficulties with cleaning services in local areas were reported by 368 units as against 175 reporting no difficulties, indicating difficulties in 68 per cent of the units reporting.

Checking back on control as against difficulties in 278 health units reporting on both, 34 per cent had both control and difficulties, 19 per cent control and no difficulties and the remaining 47 per cent neither control nor difficulties.

In response to invitation to outline any control, design, installation, servicing and maintenance practices which were found particularly successful in the local area some 367 replies were received, with the following distribution:

<u>Measures Applied</u>	<u>Number Responding</u>
State Health Department recommendations	54
Plumbing and Building Codes and Permits	49
Local Health Department control	43
Health Department design followed	36
Proper installation	28
Ordinances	24
Proper size tank	21
Use of bulletins, radio and newspaper	19
FHA design followed	16
Preinstallation inspection	14
State laws and codes	11
Cooperation of plumbing and city officials	11
Proper licensing of firms and contractors	10
Miscellaneous (1 to 6 respondents each): in- stallation of sewers, inspection, use of grease trap, proper maintenance, periodic check, di- version boxes, J. C. recommendations, elimina- tion of grease traps, hand cleaning, yeast, and plumbing department control	31
	367

Summary

1. A field of 1247 U. S. city, county and combination health units having full time health officers was circularized by questionnaire with a total response from 794, or 64 per cent of the field. This included replies ranging from acknowledgment of questionnaire with indication of no control; or no available information, to the fully executed questionnaire.

2. About 80 per cent of the 726 units, which furnished at least some information on the question of control, indicated control of some sort, lodged in the health department in practically all cases.

3. Of 44 units providing date control started, one-quarter started control before 1935 and the remainder since that time.

4. A review of ordinance material reveals a variety of items of much interest and apparent usefulness for those who wish to improve local control.

5. About 40 per cent of present installations were installed under control in areas for which installation figures were given.

6. Approximately half the units require installation permits; one-fourth, installation by skilled tradesmen. Over 60 per cent keep records of installations and complaints.

7. Weakness is shown in failure to inform householders of servicing responsibilities. Preliminary examination of installation circumstances also appears weak. However, the numbers reporting control of individual absorption system size and final inspection before backfilling appeared encouraging. With improvement in technology the latter should be effective.

8. The number of complaints ranged from 0 to 25, or more, per month for individual health units in 18 States; from 0 to less than 25 per month, per unit, in the remaining States.

9. The most frequent complaint is seepage to ground surface, followed in frequency by odor nuisance, plumbing stoppages, sewage backing into cellar, and a miscellany of other items. Causes of difficulty were most frequently clogged tile fields, tank cleaning overdue, sewer clogged, tank inlet clogged, and miscellaneous other difficulties. (Cleaners say that tank cleaning is overdue in over 50 per cent of calls).

10. Regulation of cleaning services was in effect in only one-fourth of the units. Difficulties with cleaning services were indicated by 68 per cent of the units.

11. Successful local measures reported included application of State health department recommendations, plumbing and building codes and permits, local control and design, proper installation, ordinances, proper tank, publicity, etc.

SECTION C

STUDY OF EXPERIMENTALLY OPERATED SEPTIC TANKS

STUDY OF EXPERIMENTALLY OPERATED SEPTIC TANKS

Foreword

In considering the discussion of progress on the operation of a number of household type septic tanks presented herein, the reader should bear in mind that this stage of the work is experimental. By this means it has been possible to operate and observe a variety of tanks simultaneously under controlled conditions and to condense the equivalent of some 5 to 10 years of household operation into the one year of operation conducted thus far.

Full-sized tanks were used and efforts made to simulate household dosing patterns. The sewage applied was a fresh combined sewage from a residential section of Cincinnati. The tanks are examined at this time principally on the basis of their ability to retain sewage solids, although the solids content of effluents may be but one of a number of physical, chemical and biological characteristics of possible significance in the clogging of soils. If so, then other factors of significance, when known, should become part of the basis of comparison. Some preliminary studies of effluent clogging characteristics undertaken in connection with this Project indicate a difference in clogging characteristics among several organisms isolated from an experimental septic tank effluent when applied aseptically in pure culture to a small sand column, while the killed organism similarly applied exhibited little or no such tendency within the limitations of the work done. Information from agricultural circles indicates that the biological aspects of soil clogging should be investigated.

Until such other factors as these are investigated and, if significant, taken into consideration, judgment of tank performance on the basis of solids removal alone may be of limited value. It appears safe to say, however, that whatever other characteristics may enter the final picture, tanks which exhibit poor solids removal characteristics, or require frequent servicing to compensate for capacity shortcomings, will continue in disfavor.

Introduction

In order to compare the performance of a variety of septic tanks, representing the common basic shapes in use, plans were made for building and installing several tanks at one location. The site selected for the study had to be so situated that an adequate quantity of reasonably normal fresh sewage would be available at all times. Insofar as possible, the sewage should be comparable to that discharging from the average household unit.

Several possible sites were considered in the Cincinnati area, and, after due consideration, the experimental phase of the Project was located in the greenhouse at the Environmental Health Center, Public Health Service, Cincinnati, Ohio. The site selected had several advantages, namely: a relatively large quantity of fresh domestic sewage supplied to the Station through a connection to a municipal (combined) sewer; proximity to laboratory facilities, thus simplifying sample collection and storage; fairly suitable housing facilities for the Project; a caretaker on the property; and all necessary utilities, shops, and special maintenance personnel. Following periods of rainfall, dilution of the sewage flows occurred. This was of short duration for local storms due to the rapid runoff in the hillside sewer system. The pump intake was set above the small wet well floor to provide for grit separation.

An intermittent discharge of acid from an industrial plant, the only one in the tributary area, complicated the early operating routine for about four months until discontinuance of the acid discharge to the sewer by November 5, 1947, through action taken by the City authorities. Prior to this time raw sewage pH's were checked manually before dosing the septic tanks. Any dosing tank batch found acid was dumped to waste and the tank refilled when the raw sewage became alkaline. This necessitated delay or omission of scheduled dosing on occasion. Later on, a homemade device was used to shut off the pumps delivering raw sewage

to the dosing tank whenever the pH dropped to about 6.5, the device operating on the rise in conductivity of the raw sewage.

Analytical Procedures

In the routine chemical examinations of sewage and effluent, the procedures outlined in Standard Methods for the Examination of Water and Sewage, Ninth Edition, A.P.H.A. were followed with a few minor modifications. These are outlined in Appendix C.

Raw Sewage

As stated previously, the raw sewage fed to the tanks was obtained from a combined sewer serving a residential hillside above the Station about 16 square blocks in area. The sewage itself was fresh, as time of flow from the most extreme point to the Health Center amounted to about 15 minutes. Hydrogen sulfide was never found in any of the raw sewage samples examined.

The sewage reaching the experimental plant was analyzed during the period March 31 to April 30, 1947, and the results are given in Table 26. Weighted averages of the raw sewage fed to the tanks for each series are given in Table 27. These values are composites of the material added to the tank only and do not necessarily give a true indication of the raw sewage characteristics of the total sewage flow to the Station. This statement will be clarified later when the method of feeding is described.

Data reported in Table 26 are averages of grab samples, whereas those given in Table 27 are based on averages of the composited sewages added to the various tanks.

TABLE 26.--Raw Sewage Characteristics, March 3-April 30, 1947

Determination	Number	Parts per million		
		Average	Maximum	Minimum
Total solids	21	1,257	1,978	786
Ash	21	683	1,008	374
Volatile	21	574	1,141	341
Suspended solids	21	315	744	153
Ash	20	101	194	41
Volatile	20	211	601	43
5-day B.O.D.	17	272	714	78
Oxygen consumed	19	197	411	57
Ammonia N	21	15	28	7
Organic nitrogen	19	58	99	21
Alkalinity	20	201	485	22
pH	21	7.1	7.9	2.2

TABLE 27.--Raw Sewage Characteristics, June 9, 1947--June 28, 1948

		1	2	3	4	5	6
		6/9- 8/18/47	8/30- 9/23/47	10/11- 11/9/47	11/24/47- 2/15/48	2/22- 3/28/48	3/30- 6/28/48
Total Solids	p.p.m.	986	821	1,034	1,300	1,128	1,013
T.S. Ash	p.p.m.	504	463	544	694	601	548
T.S. Volatile	p.p.m.	482	359	492	606	527	465
Suspended Solids	p.p.m.	348	312	361	550	476	440

TABLE 27.--Raw Sewage Characteristics, June 9, 1947--June 28, 1948--Cont.

		1	2	3	4	5	6
		6/9- 8/18/47	8/20- 9/23/47	10/11- 11/8/47	11/24/47- 2/15/48	2/22- 3/28/48	3/30- 6/28/48
Series							
S.S. Ash	p.p.m.	77	73	93	123	123	104
S.S. Volatile	p.p.m.	271	241	267	427	353	336
Dissolved Solids	p.p.m.	638	512	674	750	652	573
D.S. Ash	p.p.m.	427	392	450	571	478	444
D.S. Volatile	p.p.m.	212	120	222	179	174	129
PH		7.3	7.3	7.5	7.5	7.4	7.4
B.O.D. ¹		370	362	366	480	--	402

¹See Table 49 for dates of test within each series.

Septic Tanks

The first eight tanks were placed in operation June 9, 1947. Others were added at various later dates. The identification and layout of the tanks about the central dosing tank are presented in Plate 5. Descriptive detail of the individual tanks and their starting dates are presented in Tables 28 and 29, respectively. Sketches of the tanks appear in Appendix C.

TABLE 28.--Description of Septic Tanks

Tank Number	Total Liquid Capacity	Description				Remarks
		Width	Length	Diameter	Liquid Depth	
1	2,060	5'-0"	11'-0"	--	5'-0"	Rectangular Joint Committee type
2	513	2'-11"	5'-10"	--	4'-5"	Rounded ends
3	553	--	--	243'-0"	5'-3"	2-compartment vertical cylinder
4	673	--	--	492'-0"	7'-3"	4-compartment vertical cylinder
5	525	maximum 3'-4"	6'-0"	--	4'-3"	Oval
6	455	--	--	4'-4"	4'-0"	Single vertical cylinder
7	539	3'-0"	6'-0"	--	4'-0"	Rectangular Joint Committee type
8	492	--	5'-0"	4'-4"	3'-9"	Horizontal cylinder
9 ¹	539	3'-0"	6'-0"	--	4'-0"	Duplicate ¹ of No. 7
10	539	3'-0"	6'-0"	--	4'-0"	Rectangular Joint Committee type
11	539	3'-0"	6'-0"	--	4'-0"	Weir outlet
12	123	--	--	2'-0"	5'-3"	Single vertical cylinder
13	246	--	--	292'-0"	5'-3"	2-compartment vertical cylinder
14	289	--	6'+6'+3'	2'-0"	1'-6"	3-compartment horizontal cylinder
15	539	3'-0"	6'-0"	--	4'-0"	Rectangular Joint Committee type
16	539	3'-0"	3'+3'	--	4'-0"	2-compartment rectangular
17	539	3'-0"	2'+2'+2'	--	4'-0"	3-compartment rectangular
18	405	3'-0"	6'-0"	--	3'-0"	Rectangular

¹Receives ground garbage in addition to sewage.

TABLE 29.--Operating Periods For The Various Tanks Studied

Tank Number	Description	Period of Operation
1	Joint committee, rectangular, large	June 9, 1947 to June 28, 1948
2	Rounded end	June 9, 1947 to June 28, 1948
3	2-36" diameter vertical cylinder, in series	June 9, 1947 to June 28, 1948
4	4-24 inch diameter vertical cylinder, in series	June 9, 1947 to June 28, 1948
5	Prefabricated oval	June 9, 1947 to June 28, 1948
6	52-inch diameter vertical cylinder	June 9, 1947 to June 28, 1948
7	Joint Committee, rectangular small	June 9, 1947 to June 28, 1948
8	52-inch diameter horizontal cylinder	June 9, 1947 to June 28, 1948
9	Joint Committee, rectangular small, garbage and sewage	August 19, 1947 to June 28, 1948
10	Joint Committee, rectangular, small	August 20 to October 29, 1947
11	Joint Committee, rectangular, small, weir outlet	August 20 to October 29, 1947
12	1-24 inch diameter vertical cylinder	December 4, 1947 to June 28, 1948
13	2-24 inch diameter vertical cylinder	December 4, 1947 to June 28, 1948
14	3-compartment 24-inch diameter horizontal cylinder	January 5, to June 28, 1948
15	Joint Committee, rectangular small	May 3 to June 28, 1948
16	2-compartment rectangular	May 3 to June 28, 1948
17	3-compartment rectangular, small	May 3 to June 28, 1948
18	Rectangular, small, shallow depth	May 3 to June 28, 1948

Sludge

In order to avoid any lag period in digestion, which would normally occur when raw sewage is added to digestion units, and until such time as alkaline conditions would again result, sludge was brought to the laboratory from field septic tanks for seeding tanks at the start of the study. In addition, at intervals throughout the project, variable quantities of sludge, obtained from field septic tanks (with one exception when sludge from an Imhoff unit from the Glendale, Ohio, Sludge Treatment Plant was utilized), were added to the tanks to study removal efficiencies at several sludge levels, and to determine, if possible, at what level sludge would be discharged from the tanks to the absorption field or other secondary system. Such material was pooled, mixed and distributed so that each tank received portions of the same material.

Solids characteristics of the sludge added to the tanks are given in Table 30.

TABLE 30.--Field Sludge Analyses

Date	All values in p.p.m. except pH										Remarks
	T.S.	Ash	T.S.V.	S.S.	Ash	S.S.V.	D.S.	Ash	D.S.V.	pH	
6/9/47	26,960	11,103	15,851	6,401	2,615	3,867	20,479	8,488	11,984	7.1	Seed all tanks Septic tank sludge
9/29/47	24,230	11,906	12,324	22,350	10,690	11,660	1,880	1,216	664	7.3	Septic tank sludge
9/30/47	8,047	2,071	5,976	2,768	1,148	1,620	5,279	923	4,356	7.1	Septic tank sludge
10/7-8/47	68,189	41,702	26,487	64,940	40,428	24,512	3,249	1,274	1,925	(1)	Inhoff tank sludge
11/17-19/47	8,033	2,564	5,469	5,580	1,724	3,856	2,453	840	1,613	7.4	Septic tank sludge and sewage
12/4/47	18,877	8,494	10,383	18,566	8,482	10,084	311	12	299	(1)	Septic tank sludge for seed-tanks 12 and 13
1/5/48	8,572	3,821	4,751	8,040	3,408	4,632	532	413	119	7.6	Septic tank sludge for seed-tank 14
2/18/48	21,472	7,650	13,822	18,770	6,732	12,038	2,702	918	1,784	6.5	Septic tank sludge to 1
2/20/48	45,814	14,580	31,234	44,684	14,112	30,572	1,190	468	662	6.8	Septic tank sludge to 12, 13 and 14
3/29/48	30,964	15,040	15,924	30,320	14,540	15,780	644	500	144	7.6	Septic tank sludge

(1) Not determined

Seeding

As stated previously, sludge was obtained from field septic tanks for seeding the various units as they were placed in operation.

Since no definite information could be found in the literature as to the optimum amount of seed material to be added to septic tanks or other digestion systems to insure satisfactory digestion at alkaline pH levels, the decision was made to add seed material in such quantity as to amount to approximately ten per cent of the tank volume. The actual amount of seed material added to each tank is given in Table 31. Such material was pooled, mixed and distributed so that each tank received portions of the same material.

In the case of the multichambered tanks (No. 3, 2-chamber; No. 4, 4-chamber), the total volume of seed sludge was apportioned equally between the various units in each series. As a result, each unit of tank No. 3 received 25 gallons of sludge, and each unit of tank No. 4 received 12.5 gallons of sludge.

When tank No. 9 was placed in operation no seed sludge was available, so 50 gallons of sludge was taken from tank No. 1 for seed purposes since this tank had the greatest sludge volume.

Twelve and one-half gallons of sludge was added to tank No. 12 and to each of the two units comprising No. 13. In the case of tank No. 14, 29 gallons of seed sludge was placed in the first compartment of the unit.

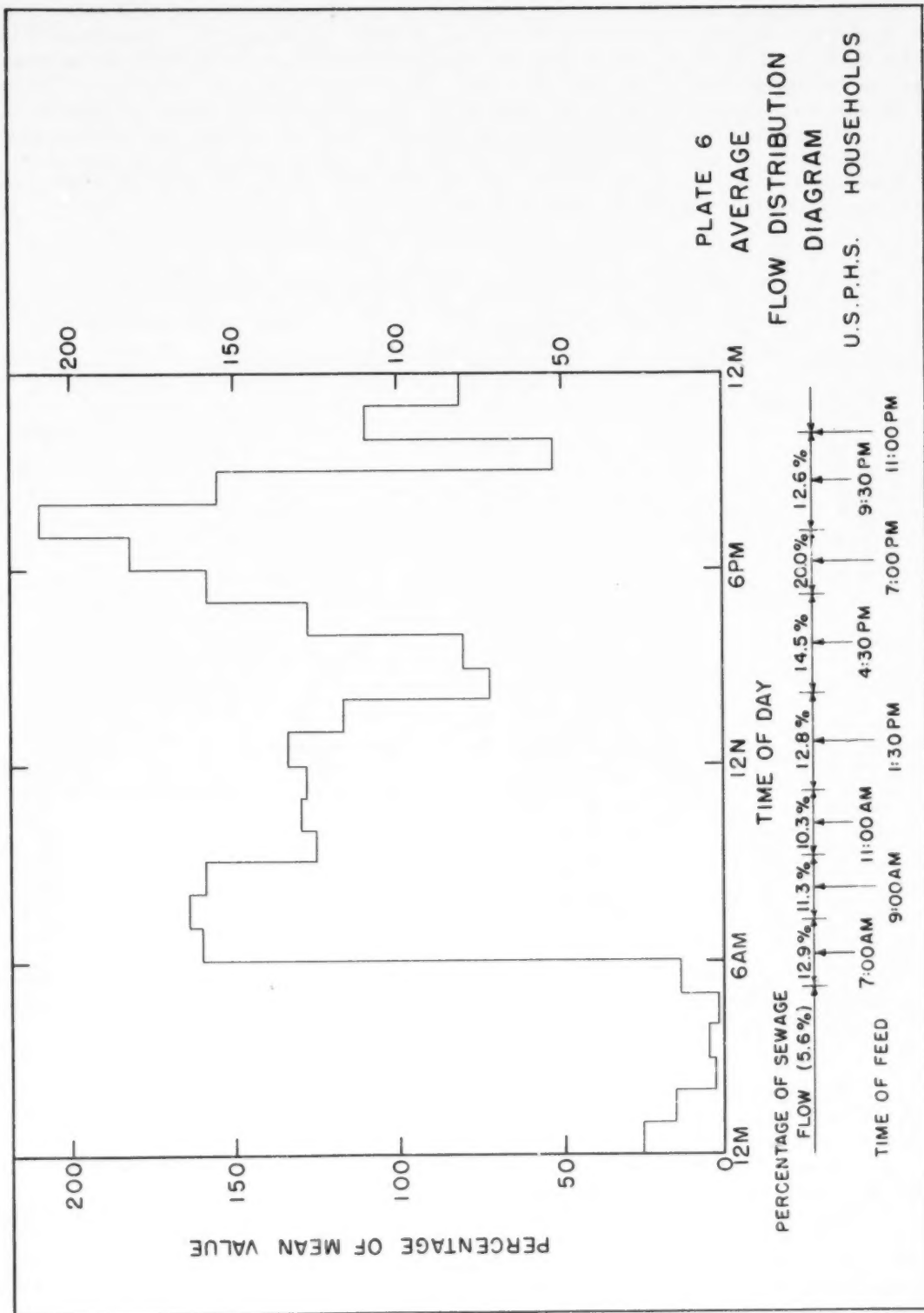
A study of the sludge volume necessary for seed purposes was made in the laboratory and will be reported on in a later section of this report.

TABLE 31.--Volume of Seed Material Added to Each Tank

Tank Number	Date of Seed	Volume of Seed-- Gallons	Source of Seed	Remarks
1	June 9, 1947	200	Field Septic Tanks	
2	June 9, 1947	50	Field Septic Tanks	
3	June 9, 1947	50	Field Septic Tanks	Volume apportioned equally to each compartment
4	June 9, 1947	50	Field Septic Tanks	Volume apportioned equally to each compartment
5	June 9, 1947	50		
6	June 9, 1947	50	Field Septic Tanks	
7	June 9, 1947	50	Field Septic Tanks	
8		50	Field Septic Tanks	
9	August 19, 1947	50	No. 1	
10	August 20, 1947	50	Field Septic Tanks	
11	August 20, 1947	50	Field Septic Tanks	
12	December 4, 1947	12.5	Field Septic Tanks	
13	December 4, 1947	25		Volume apportioned equally to each compartment
14	January 5, 1948	29	Field Septic Tanks	All seed material placed in first compartment
15	May 2, 1948	50	Field Septic Tanks	
16	May 2, 1948	50	Field Septic Tanks	Volume apportioned equally to each compartment
17	May 2, 1948	50	Field Septic Tanks	Volume apportioned equally to each compartment
18	May 2, 1948	37.5	Field Septic Tanks	

Feed Schedule

Little information is available on the actual flow of sewage from individual households. Information of this type was needed in order to intelligently determine some schedule for feeding sewage to the various septic tanks under observation. To obtain these data, recording instruments were attached to water meters in the homes of several of the Center staff. This information was averaged for the different households, percentage hourly variations in



flow were computed based on the average hourly flow, and a curve of the type shown in Plate 6, prepared. From this curve, the percentage of flow occurring within stated intervals of time could be determined. Based upon the assumption that eight feeds would be made per day at the following times, 7:00 a.m., 9:00 a.m., 11:00 a.m., 1:30 p.m., 4:30 p.m., 7:00 p.m., 9:30 p.m. and 11:00 p.m., the values obtained are shown beneath the curve in Plate 6.

The computations for converting these data to amount of sewage to be added to the tank is illustrated in Table 32. Column 3 is obtained by multiplying the values in column 2 by 500 gallons per day, the assumed daily feed to each tank. Column 4 was obtained by rounding off the values in column 3 for ease in feeding.

TABLE 32.--Computation for Volume of Sewage to be Added During Each Feed

Time of Feed (1)	Percentage of Total Feed-- Plate 6 (2)	Assuming 500 gallons/day/tank gallons (3)	Final values used in gallons	
			For 500 gallons/day (4)	For 250 gallons/day (5)
7:00 AM	12.9	64.5	65	32.5
9:00 AM	11.3	56.5	60	30
11:00 AM	10.3	51.5	50	25
1:30 PM	12.8	64.0	65	32.5
4:30 PM	14.5	72.5	70	35
7:00 PM	20.0	85.0	75	37.5
9:30 PM	12.6	63.0	65	32.5
11:00 PM	5.6	43.0	50	25

TABLE 33.--Feed Schedule--Septic Tanks

Time of Day		Amount of Feed in Gallons per Tank	
June 10, 1947- May 18, 1948	May 19, -June 28, 1948	June 10-August 18, 1947	August 20, 1947- June 28, 1948
7:00 AM	7:00 AM	65	32.5
9:00 AM	9:00 AM	60	30
11:00 AM	11:00 AM	50	25
1:30 PM	1:30 PM	65	32.5
4:30 PM	4:00 PM	70	35
7:00 PM	6:15 PM	75	37.5
9:30 PM	8:15 PM	65	32.5
10:30 PM ¹	9:45 PM	50	25
		Total	500
			250

¹This time was changed from 11:00 PM to 10:30 PM on June 23, 1947

The high value of 85 gallons was reduced to 75 gallons, because of the limiting size of the feed tank. Column 5 is obtained by dividing the value in column 4 by 2, because the flow is halved.

On June 23, 1947, the time of the 11:00 p.m. feed was changed to 10:30 p.m. and on May 19, 1948, the time of feeding was changed again as shown in Table 33.

Each tank was dosed intermittently eight times daily during the 15 to 17 hour operating day. In the first series of operation, each tank was fed a total of 500 gallons per day. In the later series, this was reduced to 250 gallons. The tanks were dosed in rotation. The intermittent doses were applied to each tank at a rate of 10 gallons per minute by manual control of a lever operated valve.

Three men, working a forty-hour week at staggered hours from 6:30 a.m. to 3:00 p.m. and from 3:00 p.m. to 11:30 p.m., operated the units seven days a week, collected the necessary data, and composited the raw sewage and effluent samples.

The following information was noted and recorded with each feed; time of feed, volume of feed, air temperatures, raw sewage temperature, depth of effluent in collecting tanks, temperature of effluent, and color of effluent. A copy of the data form is included in Appendix C. Chemical data recorded routinely included total solids, total solids ash and volatile, suspended solids, suspended solids ash and volatile, dissolved solids, dissolved solids ash and volatile, and pH. At various times determinations were made for alkalinity, grease, B.O.D., sulfides, chlorides, and dissolved oxygen.

The duration of each feed was also noted intermittently to permit comparisons of rates of feed.

Feeding and Sampling

Raw sewage from a section of Cincinnati served by combined sewers was received at the greenhouse through a special tap in the sewer line. This sewage was pumped to a feed tank (Shown in Plate 5), having a volume of 650 gallons through a 1-1/2-inch pipe by means of a 1/4 hp vertical cellar-drain type of pump connected in series with a 1/2 hp horizontal centrifugal pump. When the tank reached a predetermined level, the pumps were shut off automatically by means of a float switch. The feed tank was equipped with a three-bladed stirrer which extended to the conical portion of the feed tank. Before making the initial feed of each series, the zero level of the feed tank was established and the feed to each tank was set by means of a hook gage. A 2-inch flexible hose conveyed sewage from the feed tank to the septic tank being fed. The operator controlled the rate and amount of feed by means of a lever attached to a quick-opening valve. When the sewage in the tank reached the set hook-gage level the valve was closed, and the flexible hose was connected to the following tank. The sewage remaining in this tank after dosing the septic tanks was not wasted, but remained in the tank, and sewage for the following feed was added to this mixture. Between dosing times the contents in the feed tank were stirred continuously, and there was some opportunity for flocculation. The order of dosing the tanks was varied with each feed.

At the start of each round of doses a sample of sewage was collected from the feed tank, and was composited on the basis of quantity of sewage fed to the tanks. The sewage temperature was noted also and recorded at this time.

Septic tank effluents were collected in 55-gallon drums, a single drum serving each tank. (During the first series of operation when 500 gallons of sewage was added to the individual tanks, the effluents were caught in two 55-gallon drums connected in series. Two drums served a single unit). When the series feed was completed, the temperature of the effluent from each tank was noted along with the depth of liquid. The depth of the liquid was obtained in order to check on the accuracy of the feed. Calibration curves had been prepared for each effluent collecting tank. Simultaneously, air temperatures were taken at various points in the greenhouse. The drum contents were mixed thoroughly and a sample of the effluent was collected. These samples were then composited, according to volume fed, and the composite samples were stored in a refrigerator at a temperature of 40° F. During the compositing, the color of the effluent was noted. An arbitrary color scale based on turbidity was used, namely, light, medium, and dark. This information was desirable as an indication was obtained of the number of times a tank might discharge sludge and of the number of times feeding may have coincided with an overturn of the tank contents.

Composite Samples

The composite samples of raw sewage and septic tank effluents were brought into the laboratory each morning for tests or for further compositing with samples collected previously or to be collected. All compositing was done on a volume basis.

At the start of the experimental work, in order to determine sampling frequency, tests were made on the various solids components after each feed and also on a composite of the day's sewage feed and effluents. From the individual results, a daily composite was computed and compared with the results of the daily composite obtained by test. A summary of these results is given in Table 34. These results indicated that daily compositing would suffice. Later experiments of a similar nature indicated that samples could be composited for periods as long as one week without significant changes in the various solids fractions provided the samples were kept refrigerated (40° F.). As a result samples were composited for three days and four days and determinations were made twice weekly.

TABLE 34.--Comparison of Computed and Composite Sampling Data

		Mean $\pm$ Standard deviation		Coefficient of variation		Number of obser- vations
		Computed data	Composite data	Computed data	Composite data	
Raw Sewage--total solids	<i>p.p.m.</i>	1,056 $\pm$ 103	1,024 $\pm$ 96	9.8%	9.4%	9
Raw Sewage--suspended solids	<i>p.p.m.</i>	320 $\pm$ 65	316 $\pm$ 97	20%	31%	9
Tank 7-Js-effluent total solids	<i>p.p.m.</i>	1,247 $\pm$ 737	1,134 $\pm$ 647	59%	57%	8
Tank 7-Js-effluent suspended solids	<i>p.p.m.</i>	522 $\pm$ 662	474 $\pm$ 686	127%	145%	8

Grab Samples

A statistical study of the solids data on the individual samples taken during each feed in connection with the sampling study mentioned above, was also made, in order to determine whether the collection and analysis of grab samples during some of the field tank inspections would provide useful data. The study revealed wide variations in the individual results, and that grab sampling would not therefore be satisfactory in this connection.

Temperatures

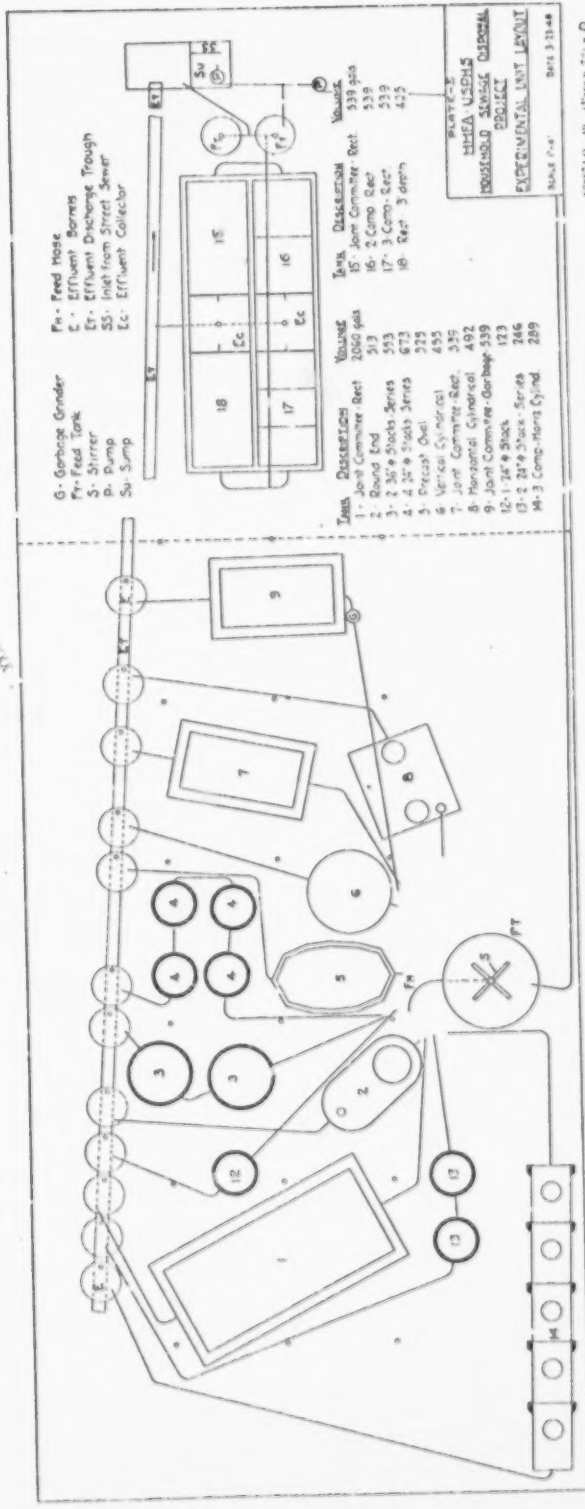
As the tanks were placed somewhat above the ground surface, it was necessary to provide heat in the greenhouse during the winter months to prevent freezing. For this purpose, one pot-belly stove and four Army surplus coal fired space heaters were utilized. By this means, air temperatures were maintained at about 5-20° C. during the feeding periods. The lowest temperature recorded was -4° C. During the summer, high air temperatures were noted ranging from 20 to 41.5° C. Tanks operated under field conditions would be under much more uniform temperature conditions than the units studied in the greenhouse.

Sewage temperatures were much more uniform than air temperatures; during the winter the temperatures ranged from 4 to 10° C. (automatic recorder finding) and during the summer months, from about 20 to 28° C.

Results

In considering the discussion of results it should be remembered that the statements made herein pertain only to the operation of the septic tank itself, and do not necessarily apply to the septic tank system, which includes, in addition to the tank itself, some means of secondary treatment or disposal.

XXXXXXXXXXXXXXXXXXXX
 See the following pages
 for greater detail.
 XXXXXXXXXXXXXXXXXXXX



Tank Performance

In one of the earlier sections descriptions were given of the various tanks under investigation. Parameters of septic tank performance in use at the present time are those generally used in the sewage treatment field, with emphasis on the solids removal characteristic, which, for the septic tank followed by ground absorption, is very important. As information develops on soil clogging characteristics of effluent, others may develop. At the present time these are not known, and the examination of performance made here is largely on the basis of solids removal. The total solids, total volatile solids, suspended solids and volatile suspended solids tests were therefore the major routine in the examination of raw sewage and tank effluents. Other determinations, such as grease, sulfides, chlorides, ammonia and B.O.D. were made at times to observe behavior in these respects.

To facilitate reporting, tank operations were based on weekly intervals. All data collected were summarized and all removals and efficiencies were computed on a weekly basis. Laboratory results were tabulated daily, twice weekly, or weekly, depending upon sample-compositing time, and from these the following quantities were computed in pounds: total solids, total volatile solids, suspended solids, and volatile suspended solids. Summation of these values permitted determinations of weekly removals of total and suspended solids by each tank and provided a means of computing tank efficiencies.

During the study several changes in operation, due to variation in the volume of daily feed to the tanks, or, to the addition of sledge at various intervals of time, were made. The intervals between such changes constitute fairly satisfactory series for comparisons of tank operation. As a result, the study has been divided into six series, or periods, for comparison. These have been designated in Table 35.

TABLE 35.--Operating Series

<u>Series</u>	<u>Duration</u>
I	June 10 - August 18, 1947
II	August 20 - September 23, 1947
III	October 11 - November 8, 1947
IV	November 24, 1947 - February 15, 1948
V	February 23 - March 28, 1948
VI	March 30 - June 28, 1948
a) Tanks 1 - 8, inclusive, in operation.	
b) Tanks 1 - 11, inclusive, in operation.	
c) Tanks 1 - 11, inclusive, in operation. Tanks 10 and 11 discontinued October 29, 1947.	
d) Tanks 1 - 9, inclusive, in operation. Tanks 12 and 13 placed in operation December 5, 1947.	
Tank 14 placed in operation January 4, 1948.	
e) Tanks 1 - 9 and 12 - 14, inclusive, in operation.	
f) Tanks 1 - 9 and 12 - 14, inclusive, in operation. Tanks 15 - 18, started May 3, 1948.	
Tanks 2 and 8 discontinued April 9, 1948.	

Series I Operation

The first series of operation (tanks 1 through 8) extended from June 10 to August 18, 1947. Five hundred gallons of fresh raw sewage were fed to each tank daily after initial seeding with field septic tank sludge.

A dosage rate of 500 gallons per day is higher than that which would normally occur in a four- or five-person household. Therefore, all tanks with the exception of tank 1 (the 2,000-gallon Joint Committee tank), which would serve more than 16 people, were overloaded. The weighted average results for this series of operation are given in Table 36, and the statistical summary of data for all series, in Table 37. Computed means, standard deviations and coefficients of variation, based on the weekly percentage solids removals, are presented in Table 38.

TABLE 36.--Sewage and Effluent Characteristics
1st Series 500 gal./day feed. June 9 - August 18, 1947

Item	Raw	1-jl	2-re	3-tl	4-ts	5-si	6-vc	7-js	8-hc	Seed Material
Raw Sewage Added gallons	33,785									
Total Solids p.p.m.	986	740	869	761	747	886	889	894	843	26,960
T. S. Ash p.p.m.	504	462	489	453	444	502	499	508	482	11,103
T. S. Volatile p.p.m.	482	278	378	310	301	384	390	386	358	15,851
Suspended Solids p.p.m.	348	149	261	147	157	284	289	288	228	6,481
S. S. Ash p.p.m.	77	53	86	41	51	100	98	101	75	2,615
S. S. Volatile p.p.m.	271	96	175	105	107	185	190	189	158	3,687
Dissolved Solids p.p.m.	638	592	605	613	591	601	596	607	611	20,479
D. S. Ash p.p.m.	427	415	401	407	394	400	398	408	408	8,488
D. S. Volatile p.p.m.	212	117	203	206	195	202	198	200	201	11,984
pH	7.3	7.5	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.1
B.O.D. p.p.m.	370	175	240	177	146	202	210	214	213	
B.O.D. reduction per cent		53%	35%	52%	61%	45%	43%	42%	42%	

The differences noted in the per cent removals based on the raw sewage added in Tables 37 and the statistical Table 38, respectively, are due to the manner of computation. The percent removal data reported in Table 37 were obtained by dividing the pounds of material removed by the tank by the pounds of material added to the tank and multiplying by 100. The percent removal values reported in Table 38 were obtained by summing up the weekly per cent removal efficiencies and dividing by the number of observations in the series (actually weeks of operation). From the above, it is evident that if the total quantity or strength of sewage added week after week varied, then the two values would vary. If, however, the quantity and strength of sewage added each week had remained constant, there would be no difference in the two series of data.

A study of the results presented in Tables 37 and 38 indicate that there were great differences in the operating efficiencies of the tanks. Tank 1 showed the highest removal which would be expected since it had the longest detention time having approximately four times the volume of the other tanks in the series. As compared to the remaining tanks, 3, and 4 were much superior in their removal efficiency. These tanks differ from the others in that they have compartments. Tank 3 has two 36-inch diameter cylinders in series, and tank 4 has four 24-inch diameter cylinders in series. The removals indicated in these two tanks are in the same order of magnitude as those indicated for the large tank of four-fold capacity. In other words, based upon the data obtained in this series, the addition of compartments in a 500-gallon tank is approximately equivalent in increasing the removal efficiency to that obtained in a rectangular tank with four times the detention period, but with no compartments.

TABLE 37.--Solids Removal Efficiencies in Per Cent--Various Series

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18*	18*
SERIES I--June 9-Aug. 18, 1947																			
	Total Solids																		
(1)	29.9	12.6	24.5	25.9	15.7	10.7	11.6	15.5											
(2)	39.7	16.0	27.4	28.7	19.0	14.2	15.0	18.8											
	Total Volatile Solids																		
(1)	45.7	21.0	36.7	37.4	21.4	19.9	20.5	25.1											
(2)	54.6	24.7	39.6	40.3	25.1	23.6	24.2	28.6											
	Suspended Solids																		
(1)	60.1	26.3	58.9	56.2	14.5	17.9	16.3	34.3											
(2)	64.0	28.3	60.0	57.3	16.7	20.1	18.6	36.1											
	Volatile Suspended Solids																		
(1)	65.1	35.6	62.0	61.1	33.4	27.1	27.2	42.0											
(2)	67.9	36.9	62.8	61.9	34.8	28.6	28.8	43.2											
SERIES II--Aug. 20-Sept. 23, 1947																			
	Total Solids																		
(1)	26.3	21.6	17.7	26.9	21.2	19.2	22.2	21.3	34.5	23.6	22.9								
(2)	37.8	16.8	26.0	28.5	19.3	14.9	16.1	19.1	38.3	28.2	27.5								
	Total Volatile Solids																		
(1)	47.1	37.7	30.8	46.0	38.5	36.1	39.6	37.4	50.3	32.2	36.2								
(2)	53.7	26.5	38.4	41.1	26.9	25.4	26.3	29.8	53.3	36.3	39.9								
	Suspended Solids																		
(1)	75.5	59.6	57.8	76.4	60.9	53.2	65.3	59.3		70.0	73.1								
(2)	65.8	33.3	59.7	60.4	23.6	25.4	26.1	39.8		71.6	74.6								
	Volatile Suspended Solids																		
(1)	76.4	60.0	62.7	77.4	65.4	59.8	66.7	63.1		68.5	71.4								
(2)	69.2	40.6	62.8	64.4	39.7	33.7	35.3	46.4		70.1	72.8								

(1) Based on raw sewage solids added during a particular series only.

(2) Based on overall addition of raw sewage solids and sludge solids, from the time tank was first put into operation to the end of a particular series.

* Period from May 3 to June 7, 1948 - leakage and overflow difficulties.

** Period from June 7 to June 28, 1948.

TABLE 37.--Solids Removal Efficiencies in Per Cent--Various Series--Cont.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18*	18*
SERIES III.-Oct. 11-Nov. 8, 1947																			
	Total Solids																		
(1)	36.2	22.3	35.0	39.1	28.1	30.8	31.3	32.8	37.7	30.7	26.2								
(2)	45.9	29.2	37.7	40.0	30.0	28.9	29.9	32.0	56.1	34.6	33.0								
	Total Volatile Solids																		
(1)	60.1	45.6	60.8	64.2	53.5	53.6	57.0	56.3	62.4	52.2	45.0								
(2)	59.7	38.3	49.3	51.6	38.0	38.3	39.2	41.7	66.8	48.2	48.1								
	Suspended Solids																		
(1)	83.6	50.3	84.2	88.8	59.1	60.6	65.6	67.3		77.2	69.7								
(2)	77.8	55.1	74.6	75.7	47.9	51.5	52.9	60.7		77.3	77.7								
	Volatile Suspended Solids																		
(1)	83.0	65.3	85.0	89.5	67.2	68.2	72.5	72.7		76.6	72.2								
(2)	76.4	54.3	72.4	74.2	52.6	50.0	52.4	59.2		74.7	75.9								
SERIES IV.-Nov. 24-Feb. 15, 1948																			
	Total Solids																		
(1)	37.7	34.2	37.9	41.6	35.2	34.4	35.3	35.6	41.2			26.1	33.6	31.8					
(2)	46.6	34.2	41.1	43.7	35.4	34.3	35.2	36.6	52.2			27.6	35.6	33.2					
	Total Volatile Solids																		
(1)	62.9	61.2	67.5	69.2	62.8	61.5	64.2	61.4	68.1			43.9	56.4	55.0					
(2)	63.7	49.1	58.3	60.2	49.8	49.5	50.8	51.5	70.6			45.2	57.8	56.2					
	Suspended Solids																		
(1)	80.5	71.7	82.9	87.8	75.4	72.7	74.7	75.7				58.2	76.7	71.3					
(2)	81.0	63.8	79.4	81.4	61.0	62.6	63.7	68.8				60.1	77.9	72.8					
	Volatile Suspended Solids																		
(1)	79.5	75.8	83.6	87.4	77.1	76.0	76.4	78.2				55.6	76.2	69.3					
(2)	79.4	64.2	77.8	80.2	64.2	62.2	63.8	68.2				57.2	77.1	70.6					

(1) Based on raw sewage solids added during a particular series only.

(2) Based on overall addition of raw sewage solids and sludge solids, from the time tank was first put into operation to the end of a particular series.

* Period from May 3 to June 7, 1948 - leakage and overflow difficulties.

** Period from June 7 to June 28, 1948.

TABLE 37.--Solids Removal Efficiencies in Per Cent--Various Series--Cont.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18*	18**
SERIES V--Feb. 23-Mar. 28, 1948																			
	Total Solids																		
(1)	29.0	20.4	34.6	39.6	25.0	26.9	26.7	17.6	42.9			22.1	28.0	32.0					
(2)	49.0	32.0	40.5	43.3	34.5	33.7	34.6	35.0	50.0			29.7	36.5	35.4					
	Total Volatile Solids																		
(1)	42.2	46.1	61.1	67.3	50.9	51.5	52.4	42.4	66.7			40.8	49.9	54.6					
(2)	65.4	48.7	58.5	60.8	50.0	49.8	51.1	50.7	69.1			47.2	57.8	56.2					
	Suspended Solids																		
(1)	58.9	47.9	79.9	88.8	60.9	57.0	63.6	39.8				51.0	70.6	77.9					
(2)	81.2	62.1	79.3	82.2	61.2	62.4	64.0	66.5				60.4	77.6	77.2					
	Volatile Suspended Solids																		
(1)	60.0	62.7	82.5	88.6	68.0	67.3	73.0	56.6				52.7	71.2	77.8					
(2)	79.4	63.8	78.2	81.0	64.8	62.9	64.9	67.2				58.4	76.8	75.6					
SERIES VI--Mar. 30-June 28, 1948																			
	Total Solids																		
(1)	32.1	12.7	26.0	37.0	18.9	11.2	26.0	11.1	23.7			2.8	9.0	-0.6	21.3	26.0	28.4	27.3	15.5
(2)	47.3	32.1	39.1	43.2	32.9	31.3	34.2	31.8	44.8			21.0	28.6	22.2	26.4	30.5	33.0	24.1	23.0
	Total Volatile Solids																		
(1)	54.5	33.0	50.7	62.3	42.9	32.7	49.1	4.0	45.8			14.7	24.5	12.1	41.4	44.0	49.6	49.0	26.8
(2)	64.5	48.3	57.9	61.7	49.6	48.1	51.6	47.7	64.3			36.0	47.3	39.0	44.6	47.2	52.8	37.3	33.4
	Suspended Solids																		
(1)	81.9	34.5	65.5	88.4	44.1	27.5	63.6	-20.2				10.2	28.3	4.1	47.2	66.9	72.7	67.6	39.9
(2)	81.8	61.4	77.9	93.6	59.7	58.6	65.1	61.0				43.7	62.5	48.9	51.3	69.6	74.4	51.7	46.3
	Volatile Suspended Solids																		
(1)	83.5	52.1	74.1	89.7	60.6	50.4	72.8	18.8				27.1	40.5	30.2	54.5	73.0	76.4	73.3	51.0
(2)	80.4	63.8	78.0	82.9	64.8	61.8	67.1	63.8				47.5	65.3	57.3	57.3	74.7	77.7	59.6	55.0

(1) Based on raw sewage solids added during a particular series only.

(2) Based on overall addition of raw sewage solids and sludge solids, from the time tank was first put into operation to the end of a particular series.

* Period from May 3 to June 7, 1948 - leakage and overflow difficulties.

** Period from June 7 to June 28, 1948.

Of the five remaining tanks, all of which were single compartment tanks of about 500 gallons capacity, tank 8 showed the highest suspended solids removal during Series I. Tank 8 was the shallowest of the five with a liquid depth of 3 feet 9 inches. Second in efficiency was the deepest of the five, tank 2, having a liquid depth of 4 feet 5 inches. Tank 8 differed somewhat from the others in that its higher inlet arrangement permitted incoming sewage to drop a greater distance before reaching the liquid surface, and the more complete mixing with the seed sludge may have been beneficial.

The differences in tank operation are further indicated in the values reported in Table 38 for the coefficient of variation which reflects the relationship between the standard deviation and the mean as shown by the expression.

$$C_v = \frac{\sigma}{M} \times 100$$

where C_v = coefficient of variation in per cent

σ = standard deviation

M = mean

The coefficients of variation ranged themselves approximately in the same order as did the removal efficiencies with one exception, and that was for the suspended and suspended volatile solids removals for tank 2. These were lower than the coefficient of variation for tank 8, but the removals were higher in the latter tank. The data indicate only that there were greater differences from the mean in the case of tank 8 than for tank 2.

On the basis of a 4-day series of tests, the B.O.D. removals varied from 35 to 61 per cent, with the highest reduction shown by the 4-chambered tank (No. 4). The 2,000 gallon tank (No. 1) and the 2-chambered tank (No. 3) also had B.O.D. removals in the same high range.

Series II Operation

On August 20, 1947, the feed was reduced to 250 gallons per day per tank, and all tanks were fed at this rate until September 23, 1947. The results obtained during this interval of operation (second series) are given in summary form in Tables 37, 38 and 39. A reduction in the quantity of sewage feed had a marked effect on the removal efficiencies in that removals were increased materially. Two of the tanks (1 and 4) showing the highest removals in the first series of operation, continued to show high removals (above 75 per cent for suspended solids). Tank 3 remained constant; the remaining 500 gallon tanks showed considerable increase in removal efficiency particularly in the suspended and suspended volatile solids. The differences in tank performance which were so obvious in the first series are much less in evidence in the second series data. Apparently, a reduction in flow vitiates to some extent at least tank design.

B.O.D. reductions based on a 10-day series of tests, were in general, somewhat greater in this series than in the previous one ranging from 49 to 60 per cent.

At the start of this series three additional tanks were placed in operation; tank 9, which received garbage in addition to the normal sewage load; tank 10, which served as a Joint Committee control tank to study the effect of modifying the outlet; and tank 11, a modified Joint Committee tank with a weir outlet. The latter tanks are described more fully and the results obtained in their operation are presented in the section entitled "Inlet and Outlet Studies." Tank 9 will be compared with tank 7, its counterpart, in a later discussion.

Since the coefficients of variation in Table 38 for series 2 operation indicate much lower values than in the previous series, we may conclude that tank operation was more uniform and without the intermittent slug discharges noted before.

Series III Operation

A mixture of approximately 200 gallons of septic tank sludge, obtained from field septic tanks and Imhoff tank sludge from the Glendale, Ohio, municipal sewage treatment plant, was added to each of the tanks on September 29-30 and October 7-8, 1947 to raise the sludge levels in the tank. This was done to study tank operation under simulated field conditions

TABLE 38.--Statistical

	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8
Series 1	24.90 ± 4.16	14.31 ± 4.85	23.31 ± 2.98	23.50 ± 4.48	13.61 ± 5.81	9.01 ± 5.80	12.05 ± 6.74	16.18 ± 4.16
Series 2	25.73 ± 4.11	21.16 ± 3.40	17.26 ± 6.94	26.28 ± 5.46	20.90 ± 4.32	19.05 ± 3.72	21.80 ± 3.42	21.02 ± 4.11
Series 3	35.04 ± 6.80	22.85 ± 20.39	33.98 ± 8.39	37.74 ± 7.06	28.75 ± 3.88	28.51 ± 8.47	29.90 ± 12.14	31.82 ± 6.80
Series 4	36.97 ± 9.09	33.98 ± 8.61	37.80 ± 6.55	41.67 ± 7.04	31.65 ± 10.66	34.27 ± 12.98	35.01 ± 7.93	35.48 ± 9.09
Series 5	19.65 ± 17.90	18.70 ± 27.00	33.46 ± 14.34	38.77 ± 13.08	25.11 ± 16.56	26.98 ± 18.09	25.57 ± 23.16	16.14 ± 17.90
Series 6	32.39 ± 5.21	12.58 ± 14.86	26.52 ± 12.88	37.12 ± 5.64	18.09 ± 16.39	11.38 ± 18.16	26.47 ± 9.63	-11.64 ± 5.21
Series 1	16.7	33.9	12.8	19.1	42.7	64.4	55.9	34.9
Series 2	16.0	16.1	40.2	20.8	20.7	17.7	15.7	18.6
Series 3	19.4	89.2	24.7	18.7	13.5	29.7	40.6	20.0
Series 4	24.6	25.3	22.6	16.9	33.7	37.9	22.6	26.2
Series 5	91.1	144.4	42.9	33.7	66.0	67.0	90.5	171.3
Series 6	16.1	118.2	48.6	15.2	90.7	159.5	36.4	-197.0
Total Volat								
Series 1	41.23 ± 5.26	21.86 ± 8.21	37.33 ± 4.58	35.21 ± 5.55	19.08 ± 16.75	17.66 ± 8.10	21.24 ± 8.73	26.40 ± 5.26
Series 2	45.78 ± 8.11	50.75 ± 17.14	30.25 ± 8.28	44.86 ± 7.94	37.81 ± 8.64	35.92 ± 9.11	38.87 ± 6.35	36.97 ± 8.11
Series 3	59.20 ± 5.42	45.12 ± 25.35	60.09 ± 9.01	62.52 ± 9.66	54.10 ± 5.97	50.57 ± 10.08	55.04 ± 14.73	56.11 ± 5.42
Series 4	61.85 ± 6.55	60.14 ± 7.07	66.47 ± 7.26	68.28 ± 6.98	61.30 ± 10.76	59.89 ± 12.24	60.72 ± 8.11	59.67 ± 6.55
Series 5	37.77 ± 19.80	38.71 ± 35.58	57.02 ± 16.90	64.34 ± 12.71	46.12 ± 21.70	47.36 ± 24.97	46.07 ± 29.58	33.40 ± 19.80
Series 6	54.54 ± 7.83	33.31 ± 15.63	50.72 ± 12.87	62.19 ± 6.05	40.48 ± 21.64	32.50 ± 20.46	48.83 ± 11.90	-2.95 ± 7.83
Series 1	12.7	37.6	12.3	15.7	87.8	45.9	41.1	34.4
Series 2	17.7	33.8	36.6	17.7	22.8	25.4	16.4	16.5
Series 3	9.2	56.1	15.0	15.4	11.0	20.0	26.8	13.3
Series 4	10.6	11.8	10.9	10.2	17.5	20.5	13.4	17.5
Series 5	52.5	92.0	29.6	19.8	47.1	52.6	64.1	115.0
Series 6	14.4	46.9	25.4	9.7	53.5	63.0	24.4	-1,062.0
Suspended								
Series 1	57.27 ± 5.71	30.90 ± 8.49	58.84 ± 12.18	54.36 ± 15.13	13.31 ± 18.89	16.60 ± 18.17	20.03 ± 14.55	39.51 ± 5.71
Series 2	74.70 ± 5.15	59.40 ± 5.77	57.54 ± 7.79	75.80 ± 8.51	61.15 ± 5.98	54.12 ± 11.35	65.03 ± 7.94	59.49 ± 5.15
Series 3	83.78 ± 2.21	56.05 ± 38.76	84.63 ± 3.91	88.95 ± 1.70	63.64 ± 24.50	60.40 ± 8.09	68.06 ± 17.73	68.83 ± 2.21
Series 4	78.79 ± 8.34	68.92 ± 14.65	81.23 ± 9.80	87.03 ± 4.62	73.24 ± 12.46	70.12 ± 27.22	73.15 ± 11.74	73.89 ± 8.34
Series 5	55.98 ± 12.17	38.54 ± 55.27	77.60 ± 8.07	88.06 ± 3.81	62.06 ± 12.59	56.65 ± 25.99	59.05 ± 35.08	31.11 ± 12.17
Series 6	81.44 ± 6.20	35.43 ± 25.95	64.17 ± 21.69	88.11 ± 3.43	40.09 ± 35.69	29.59 ± 38.05	63.69 ± 18.65	-19.52 ± 6.20
Series 1	10.0	27.5	20.7	27.8	142.	109.5	72.6	45.2
Series 2	6.9	9.7	13.5	11.2	9.8	20.9	12.2	12.3
Series 3	2.7	69.0	4.6	1.9	38.6	13.4	26.0	16.7
Series 4	10.6	21.3	12.1	5.3	17.0	38.9	16.1	13.7
Series 5	21.8	143.5	10.4	4.3	20.3	45.9	59.5	193.0
Series 6	7.6	73.3	33.8	3.9	88.3	128.4	29.3	-182.2
Suspended Vol								
Series 1	63.85 ± 5.20	39.64 ± 8.02	61.93 ± 10.69	59.73 ± 12.64	32.03 ± 26.19	28.93 ± 11.12	29.72 ± 15.96	46.73 ± 5.20
Series 2	75.13 ± 6.73	59.72 ± 6.09	61.87 ± 6.17	75.91 ± 8.76	65.18 ± 5.49	59.99 ± 6.32	65.83 ± 6.84	62.84 ± 6.73
Series 3	83.53 ± 2.55	67.89 ± 18.81	85.55 ± 3.97	89.79 ± 2.37	70.72 ± 15.96	68.42 ± 5.64	73.80 ± 11.30	74.00 ± 2.55
Series 4	77.24 ± 8.75	72.71 ± 14.09	81.64 ± 8.65	86.42 ± 4.75	74.47 ± 11.35	72.99 ± 20.22	74.30 ± 10.62	76.23 ± 8.75
Series 5	56.26 ± 12.55	52.41 ± 42.27	80.12 ± 7.29	87.55 ± 4.41	66.18 ± 14.44	65.63 ± 19.95	67.80 ± 27.05	46.23 ± 12.55
Series 6	82.80 ± 6.45	53.76 ± 17.02	73.04 ± 14.48	89.43 ± 3.99	57.81 ± 22.42	51.83 ± 23.04	72.27 ± 13.34	19.87 ± 6.45
Series 1	8.1	20.2	17.3	21.2	81.7	38.5	53.7	32.1
Series 2	9.0	10.2	10.0	11.5	8.4	10.5	10.4	8.6
Series 3	3.0	27.7	4.6	2.6	22.6	8.2	15.3	12.8
Series 4	11.3	19.4	10.6	5.5	15.3	27.8	14.3	10.7
Series 5	22.4	80.6	9.1	5.0	21.9	30.4	39.9	103.0
Series 6	7.8	31.7	20.0	4.5	38.8	43.4	18.4	116.2

38.--Statistical Summary, Solids Data, Percentage Removals

Tank 7	Tank 8	Tank 9	Tank 10	Tank 11	Tank 12	Tank 13	Tank 14	Tank 15	Tank 16
Total Solids, Mean $\pm$ Standard Deviation									
± 6.74	16.18 ± 5.66	--	--	--	--	--	--	--	--
± 3.42	21.02 ± 3.92	35.83 ± 10.48	26.04 ± 5.97	23.89 ± 4.40	--	--	--	--	--
± 12.14	31.82 ± 16.38	35.84 ± 9.88	--	--	--	--	--	--	--
± 7.93	35.48 ± 9.32	41.19 ± 8.24	--	--	26.02 ± 9.17	33.61 ± 9.12	32.40 ± 12.86	--	--
± 23.16	16.14 ± 27.67	42.82 ± 9.64	--	--	25.31 ± 13.63	27.10 ± 14.17	31.30 ± 11.57	--	--
± 9.63	-11.64 ± 22.95	22.86 ± 22.77	--	--	2.67 ± 8.77	9.12 ± 10.99	0.33 ± 9.53	21.95 ± 13.02	25.96 ± 6.40
Coefficients of Variation									
9	34.9	--	--	--	--	--	--	--	--
7	18.6	29.3	22.9)	18.4)	--	--	--	--	--
6	20.0	27.6	--	--	--	--	--	--	--
6	26.2	20.0	--	--	35.2	27.1	39.7	--	--
5	171.3	22.5	--	--	53.9	52.3	56.9	--	--
4	-197.0	99.6	--	--	329.	120.8	289.0	59.3	25.7
Total Volatile Solids, Mean $\pm$ Standard Deviation									
± 8.73	26.40 ± 9.07	--	--	--	--	--	--	--	--
± 6.35	36.97 ± 6.10	50.72 ± 12.85	39.63 ± 12.14	39.17 ± 7.43	--	--	--	--	--
± 14.73	56.11 ± 7.46	60.68 ± 11.38	--	--	--	--	--	--	--
± 8.11	59.67 ± 10.44	67.22 ± 6.07	--	--	42.20 ± 11.52	54.96 ± 11.47	54.48 ± 7.66	--	--
± 29.58	33.40 ± 38.42	65.50 ± 10.73	--	--	36.68 ± 21.63	45.54 ± 21.68	50.34 ± 18.75	--	--
± 11.90	-2.95 ± 31.37	45.34 ± 25.60	--	--	14.34 ± 15.10	23.23 ± 19.08	11.74 ± 19.55	41.47 ± 17.74	43.61 ± 6.40
Coefficients of Variation									
1	34.4	--	--	--	--	--	--	--	--
4	16.5	25.4	30.6)	18.9)	--	--	--	--	--
8	13.3	18.8	--	--	--	--	--	--	--
4	17.5	9.0	--	--	27.3	20.9	14.0	--	--
1	115.0	16.4	--	--	59.0	47.6	37.2	--	--
4	-1,062.0	56.5	--	--	105.2	82.1	166.7	42.8	14.7
Suspended Solids, Mean $\pm$ Standard Deviation									
± 14.55	39.51 ± 17.85	--	--	--	--	--	--	--	--
± 7.94	59.49 ± 7.34	--	71.82 ± 8.14	71.29 ± 5.28	--	--	--	--	--
± 17.73	68.83 ± 11.49	--	--	--	--	--	--	--	--
± 11.74	73.89 ± 10.10	--	--	--	54.18 ± 17.67	74.59 ± 8.23	70.76 ± 5.06	--	--
± 35.08	31.11 ± 59.96	--	--	--	48.62 ± 12.98	68.91 ± 9.23	76.92 ± 6.33	--	--
± 18.65	-19.52 ± 35.59	--	--	--	8.97 ± 19.03	26.73 ± 23.10	0.70 ± 39.70	46.01 ± 25.85	66.23 ± 10.40
Coefficients of Variation									
6	45.2	--	--	--	--	--	--	--	--
2	12.3	--	11.3)	7.4)	--	--	--	--	--
0	16.7	--	--	--	--	--	--	--	--
1	13.7	--	--	--	32.6	11.0	7.2	--	--
5	193.0	--	--	--	26.7	13.4	8.2	--	--
3	-182.2	--	--	--	212.0	86.5	5,670.	56.1	15.9
Suspended Volatile Solids, Mean $\pm$ Standard Deviation									
± 15.96	46.73 ± 14.99	--	--	--	--	--	--	--	--
± 6.84	62.84 ± 5.37	--	70.56 ± 7.69	71.04 ± 5.15	--	--	--	--	--
± 11.30	74.00 ± 9.46	--	--	--	--	--	--	--	--
± 10.62	76.23 ± 8.13	--	--	--	50.54 ± 21.09	73.57 ± 8.27	68.71 ± 5.82	--	--
± 27.05	45.23 ± 47.70	--	--	--	49.54 ± 13.36	69.06 ± 9.70	76.62 ± 6.77	--	--
± 13.34	19.87 ± 17.10	--	--	--	26.17 ± 18.20	37.98 ± 22.01	29.15 ± 34.81	53.33 ± 21.60	72.35 ± 7.40
Coefficients of Variation									
7	32.1	--	--	--	--	--	--	--	--
4	8.6	--	10.9)	7.2)	--	--	--	--	--
3	12.8	--	--	--	--	--	--	--	--
3	10.7	--	--	--	41.8	11.2	8.5	--	--
9	103.0	--	--	--	27.0	14.0	8.8	--	--
4	116.2	--	--	--	69.6	58.1	119.4	40.6	10.8

B

Percentage Removals

78'12

	Tank 11	Tank 12	Tank 13	Tank 14	Tank 15	Tank 16	Tank 17	Tank 18
iation								
97)	23.89 ± 4.40)	-- -- --						
		26.02 ± 9.17 25.31 ± 13.63 2.67 ± 8.77	33.61 ± 9.12 27.10 ± 14.17 9.12 ± 10.99	32.40 ± 12.86 31.30 ± 11.57 0.33 ± 9.53	21.95 ± 13.02	25.96 ± 6.68	28.19 ± 7.13	15.05 ± 9.48 28.30 ± 7.62)
	18.4)	-- -- --						
		35.2 53.9 329.	27.1 52.3 120.8	39.7 36.9 289.0	59.3	25.7	25.3	63.0) 27.0)
Deviation								
14)	39.17 ± 7.43)	-- -- --						
		42.20 ± 11.52 36.68 ± 21.63 14.34 ± 15.10	54.96 ± 11.47 45.54 ± 21.68 23.23 ± 19.08	54.48 ± 7.66 50.34 ± 18.75 11.74 ± 19.55	41.47 ± 17.74	43.61 ± 6.41	49.06 ± 10.94	26.35 ± 12.57 49.93 ± 4.48)
	18.9)	-- -- --						
		27.3 59.0 105.2	20.9 47.6 82.1	14.0 37.2 166.7	42.8	14.7	22.3	47.7) 9.0)
Deviation								
14)	71.29 ± 5.28)	-- -- --	--	--				
		54.18 ± 17.67 48.62 ± 12.98 8.97 ± 19.03	74.59 ± 8.23 68.91 ± 9.23 26.73 ± 23.10	70.76 ± 5.06 76.92 ± 6.33 0.70 ± 39.70	46.01 ± 25.85	66.23 ± 10.54	71.64 ± 10.01	35.77 ± 25.67 65.37 ± 2.21)
	7.4)	-- -- --						
		32.6 26.7 212.0	11.0 13.4 86.5	7.2 8.2 5,670.	56.1	15.9	14.0	71.8) 3.4)
ard Deviation								
69)	71.04 ± 5.15)	-- -- --						
		50.54 ± 21.09 49.54 ± 13.36 26.17 ± 18.20	73.57 ± 8.27 69.06 ± 9.70 37.98 ± 22.01	68.71 ± 5.82 76.62 ± 6.77 29.15 ± 34.81	53.33 ± 21.60	72.35 ± 7.78	75.35 ± 8.98	47.74 ± 19.31 73.75 ± 3.26)
	7.2)	-- -- --						
		41.8 27.0 69.6	11.2 14.0 58.1	8.5 8.8 119.4	40.6	10.8	11.9	40.5) 4.4)

of variable sludge level, and the effect these sludge levels would have on solids removal efficiencies. Fresh raw sewage was added to each tank at the rate of 250 gallons per day per tank during the period October 3 to November 8, 1947. This period is identified as the third series of operation.

TABLE 39.--Sewage and Effluent Characteristics

2nd Series. 250 gal./day, August 20-September 23, 1947

Item	Raw	1	2	3	4	5	6	7	8	9	10	11	
Raw Sewage Added	<i>gallons</i>	7,492.5											
Total Solids	<i>p.p.m.</i>	821	609	646	669	600	648	666	642	647	716	629	634
T. S. Ash	<i>p.p.m.</i>	463	418	421	420	409	428	436	422	424	424	385	405
T. S. Volatile	<i>p.p.m.</i>	359	191	224	249	193	221	230	218	226	292	244	229
Suspended Solids	<i>p.p.m.</i>	312	76	125	131	73	122	146	109	127	193	94	84
S. S. Ash	<i>p.p.m.</i>	73	18	49	41	19	39	50	28	39	19	18	15
S. S. Volatile	<i>p.p.m.</i>	241	59	89	91	53	83	96	80	88	84	76	69
Dissolved Solids	<i>p.p.m.</i>	512	533	520	538	527	527	520	532	520	613	535	550
D. S. Ash	<i>p.p.m.</i>	392	400	385	378	388	388	386	390	385	405	367	390
D. S. Volatile	<i>p.p.m.</i>	120	133	136	159	141	139	133	138	137	208	168	160
pH		7.3	7.5	7.4	7.4	7.4	7.5	7.5	7.4	7.4	7.3	7.4	7.4
B.O.D.	<i>p.p.m.</i>	362	147	166	172	146	162	160	176	185	256		
B.O.D.	<i>reduction per cent</i>		59%	54%	52%	60%	55%	56%	51%	49%	29%		

During this period, greater removals were obtained than in the former series. The total and total volatile solids values increased markedly with the highest removal indicated by tank 4, tank 3 and tank 1. With the exception of tank 2, most of the remaining tanks were grouped. In the case of the removal of suspended and suspended volatile solids, which ranged from 50 to 89 per cent and 65 to 90 per cent, respectively, the highest removals were shown by tanks 4, 3 and 1, and the lowest by tank 2.

Here again, as in the previous instance, the coefficients of variation were somewhat lower. The values obtained for tanks 1, 3, and 4 were 2.7, 4.6 and 1.9 per cent respectively, for the suspended solids, whereas the widest variation is indicated for tank 2 with a C_v value of 69.0 per cent.

B.O.D. reductions were higher during this series than previously, ranging from 65 to 82 per cent, with the highest reduction shown by the 4-chambered tank. The results of operation are shown in Tables 37, 38, and 40.

Series IV Operation

The fourth series of operation began with the addition of about 300 gallons of sludge from field septic tanks on November 17 and 18, 1947. Fresh raw sewage was added at a rate of 250 gallons per day per tank during the period November 24, 1947 to February 15, 1948. During this period three additional tanks were put in operation to study the removal efficiencies to be expected with small sized tanks. The tanks added were tank 12, a 24-inch diameter vertical cylindrical tank of 123 gallons capacity; 13, two 24-inch vertical cylindrical tanks in series totalling 246 gallons capacity; and tank 14, a three compartment 24-inch diameter horizontal cylindrical tank of 289 gallons capacity.

In general, as noted in Tables 37, 38 and 40, there was a further increase in the solids removals during the series. From this, it is apparent that a certain amount of sludge, or, at least, the type of sludge and the manner of feeding followed here, may be beneficial and will result in higher operating efficiencies. This notwithstanding the fact, that the volume of sewage fed to the tanks remained constant and that, theoretically, the theoretical detention time was decreased somewhat by increased sludge accumulations. This increase in apparent sludge volume is noted in Plates 7 to 12, inclusive, which show cumulative sludge accumulations as a function of time.

TABLE 40.--Sewage + Effluent Characteristics
3rd Series. October 3-November 8, 1947. 250 gal./day Feed
After Addition of Sludge to Build Up Volume.

Item	Raw	1	2	3	4	5	6	7	8	9	10	11	
Raw Sewage Added	<i>gallons</i>	7,577.5											
Total Solids	<i>p.p.m.</i>	1,034	667	808	687	648	756	724	716	711	721	643	685
T. S. Ash	<i>p.p.m.</i>	544	461	537	488	460	517	489	484	481	504	453	466
T. S. Volatile	<i>p.p.m.</i>	492	207	273	200	187	237	236	231	228	217	190	219
Suspended Solids	<i>p.p.m.</i>	361	59	183	61	43	147	144	123	120	123	75	100
S. S. Ash	<i>p.p.m.</i>	93	13	84	18	13	56	56	46	43	44	20	35
S. S. Volatile	<i>p.p.m.</i>	267	45	99	44	32	90	88	75	78	79	55	65
Dissolved Solids	<i>p.p.m.</i>	674	609	626	627	604	609	581	594	590	598	568	585
D. S. Ash	<i>p.p.m.</i>	450	446	452	470	448	463	430	438	439	460	433	431
D. S. Volatile	<i>p.p.m.</i>	222	162	173	157	157	147	147	155	152	138	135	154
pH		7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.5	7.5	7.5	7.5	7.5
B.O.D.	<i>p.p.m.</i>	366	94	128	85	66	85	84	99	100	92		
B.O.D.	<i>reduction per cent</i>		74	65	77	82	77	77	73	73	75		
Grease		100	10	13	8	12	19	21	22	29	28		
Grease	<i>reduction per cent</i>		90	87	92	88	81	79	78	71	72		

Suspended solids removals in the order of 72 to 88 per cent were noted and B.O.D. removals of 71 and 77 per cent. As in the previous series the highest removals in suspended solids were obtained in the multichambered tanks. The coefficients of variation increased in some instances and decreased in others, but they were still relatively low.

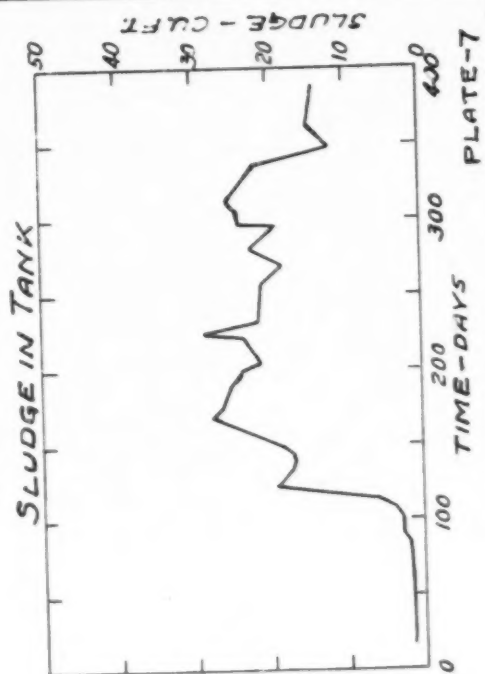
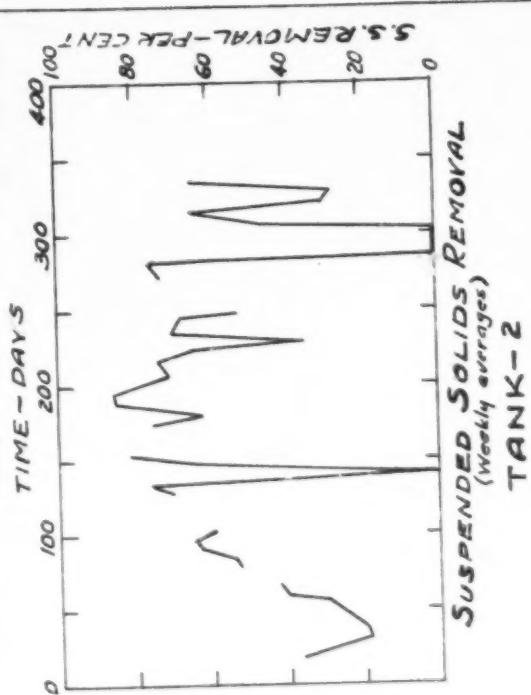
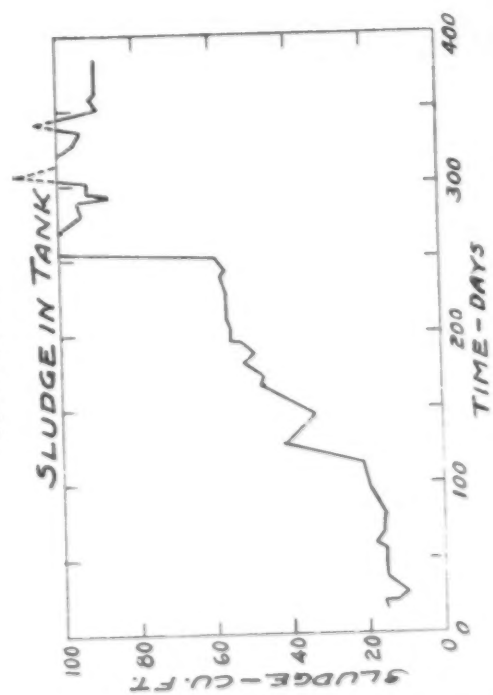
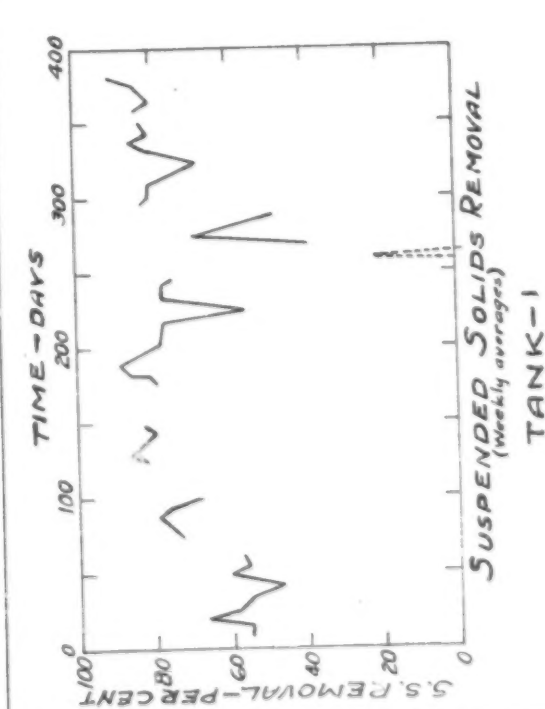
A study of Plates 7 to 12, inclusive, will reveal that during this series many of the tanks reached peak levels of sludge accumulations, and that thereafter sludge levels appeared to decrease. This situation was generally true for all of the single chambered tanks that had been in operation since June 1947. Sludge accumulations will be discussed more fully in a later section of the report.

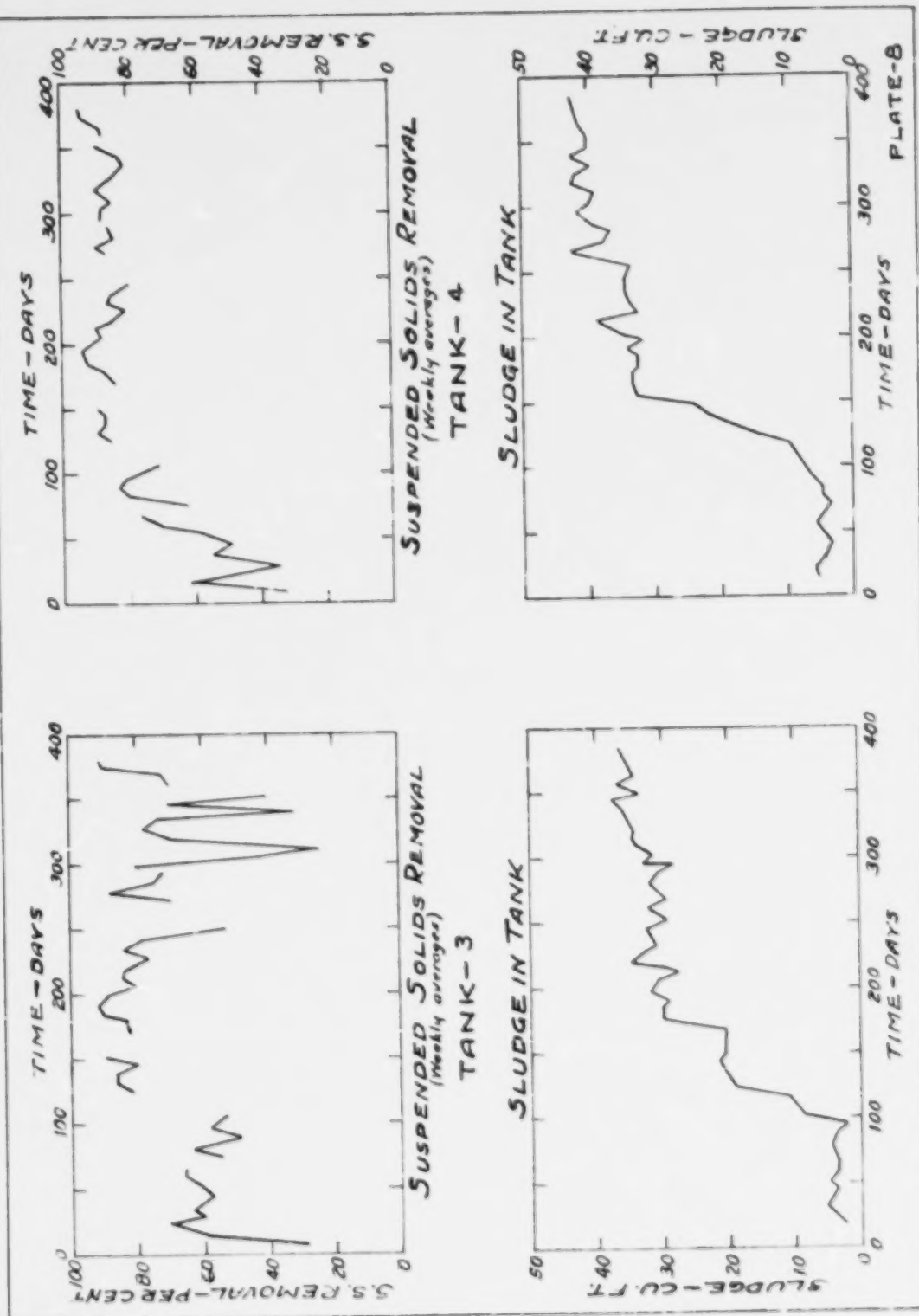
During the second, third, and fourth series a rapid increase in removal efficiency was noted for all tanks, and this increase it was thought, might be due to the increased sludge volume in the tanks. The ratio of sludge volume to tank volume increase much more rapidly for the smaller single-chambered tanks than it did in the large 2,000 gallon tank.

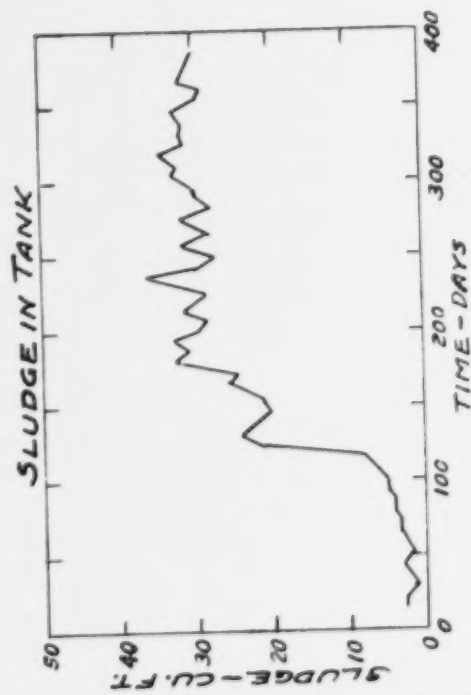
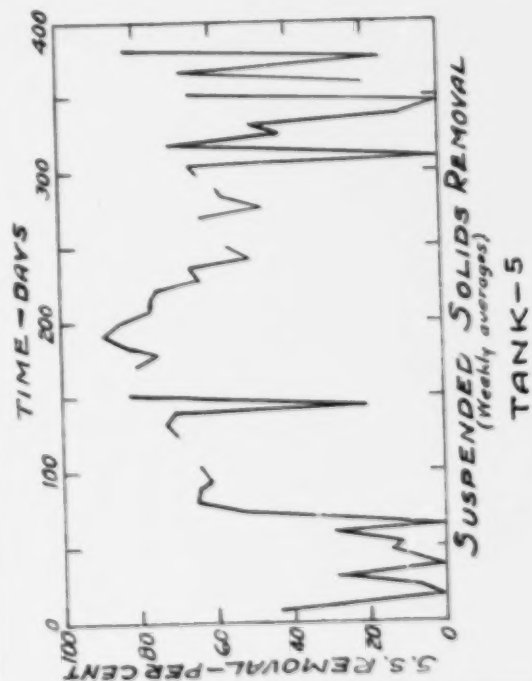
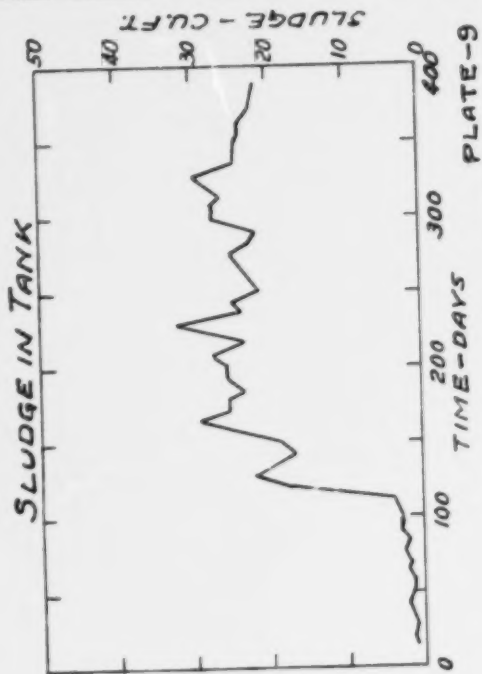
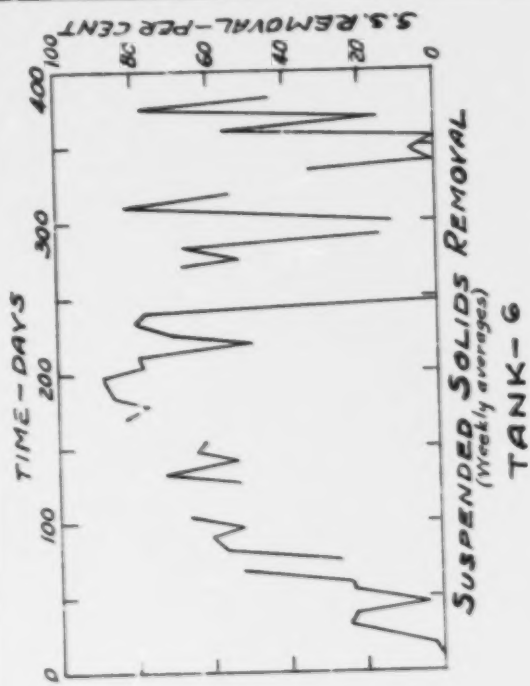
TABLE 41.--Sewage and Effluent Characteristics
4th Series. 250 gal./day Feed. November 24, 1947-February 15, 1948

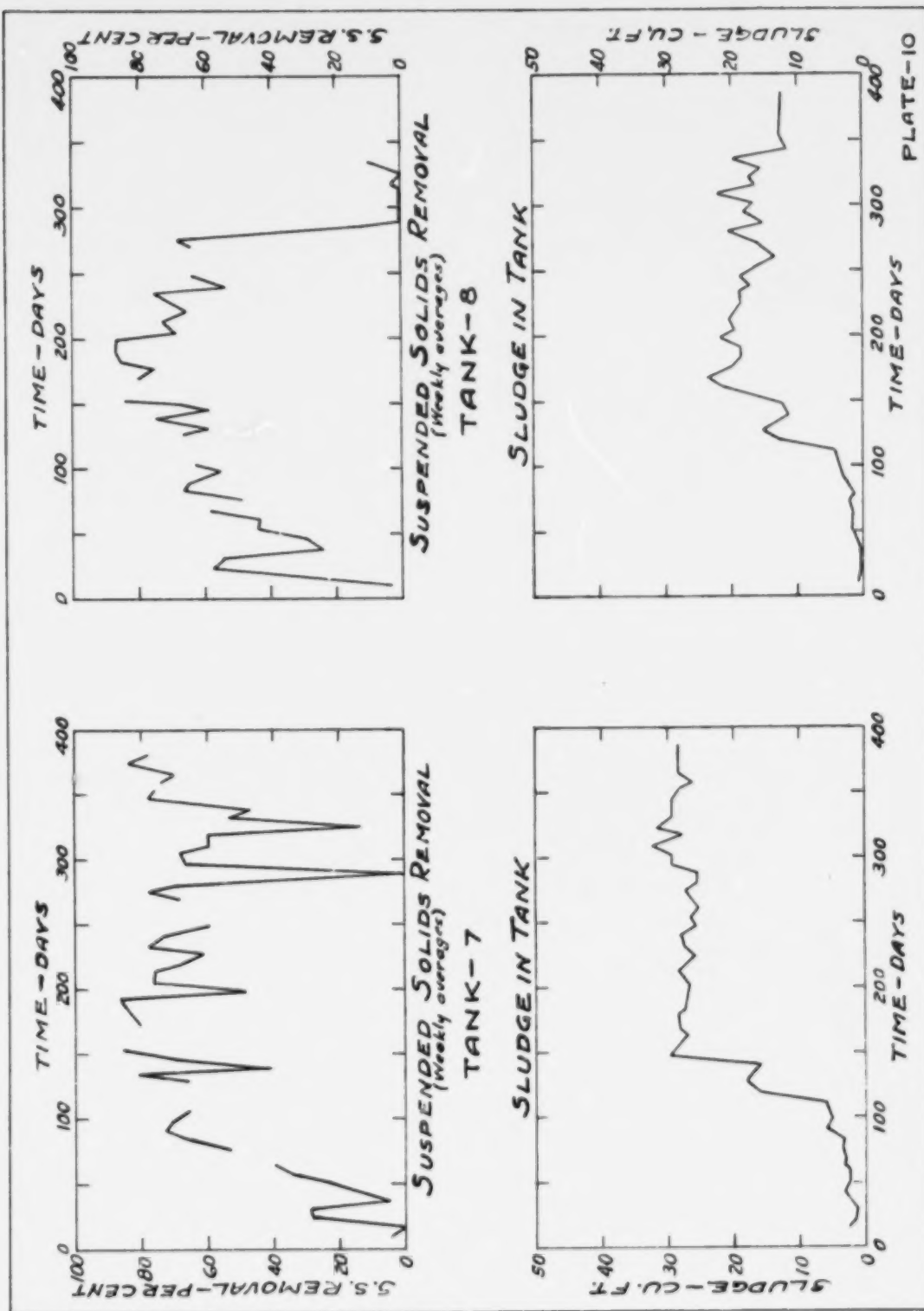
Item	Raw	1	2	3	4	5	6	7	8	9	12	13	14	
Raw Sewage Added														
	<i>gallons</i>	18,275.0												
Total Solids	<i>p.p.m.</i>	1,300	781	856	808	697	773	758	772	715	819	970	872	800
T. S. Ash	<i>p.p.m.</i>	694	565	621	611	526	566	553	573	522	602	628	617	570
T. S. Volatile	<i>p.p.m.</i>	606	216	235	197	171	207	205	199	193	217	342	255	230
Suspended Solids														
	<i>p.p.m.</i>	550	104	155	94	62	124	133	128	114	118	230	129	123
S. S. Ash	<i>p.p.m.</i>	123	19	52	24	12	34	42	35	35	26	40	27	24
S. S. Volatile	<i>p.p.m.</i>	427	85	103	70	50	90	91	93	79	92	190	102	99
Dissolved Solids														
	<i>p.p.m.</i>	750	677	701	714	635	649	625	644	601	701	740	743	677
D. S. Ash	<i>p.p.m.</i>	571	546	569	587	514	532	511	538	487	576	588	590	546
D. S. Volatile	<i>p.p.m.</i>	179	131	132	127	121	117	114	106	114	125	152	153	131
pH		7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.5	7.5	7.5	7.6	7.5
B.O.D.		480	144	130	137	131	134	127	114	124	112	268 ¹	230 ¹	
B.O.D.														
	<i>reduction per cent</i>		70	73	71	73	72	74	76	74	77	44	52	

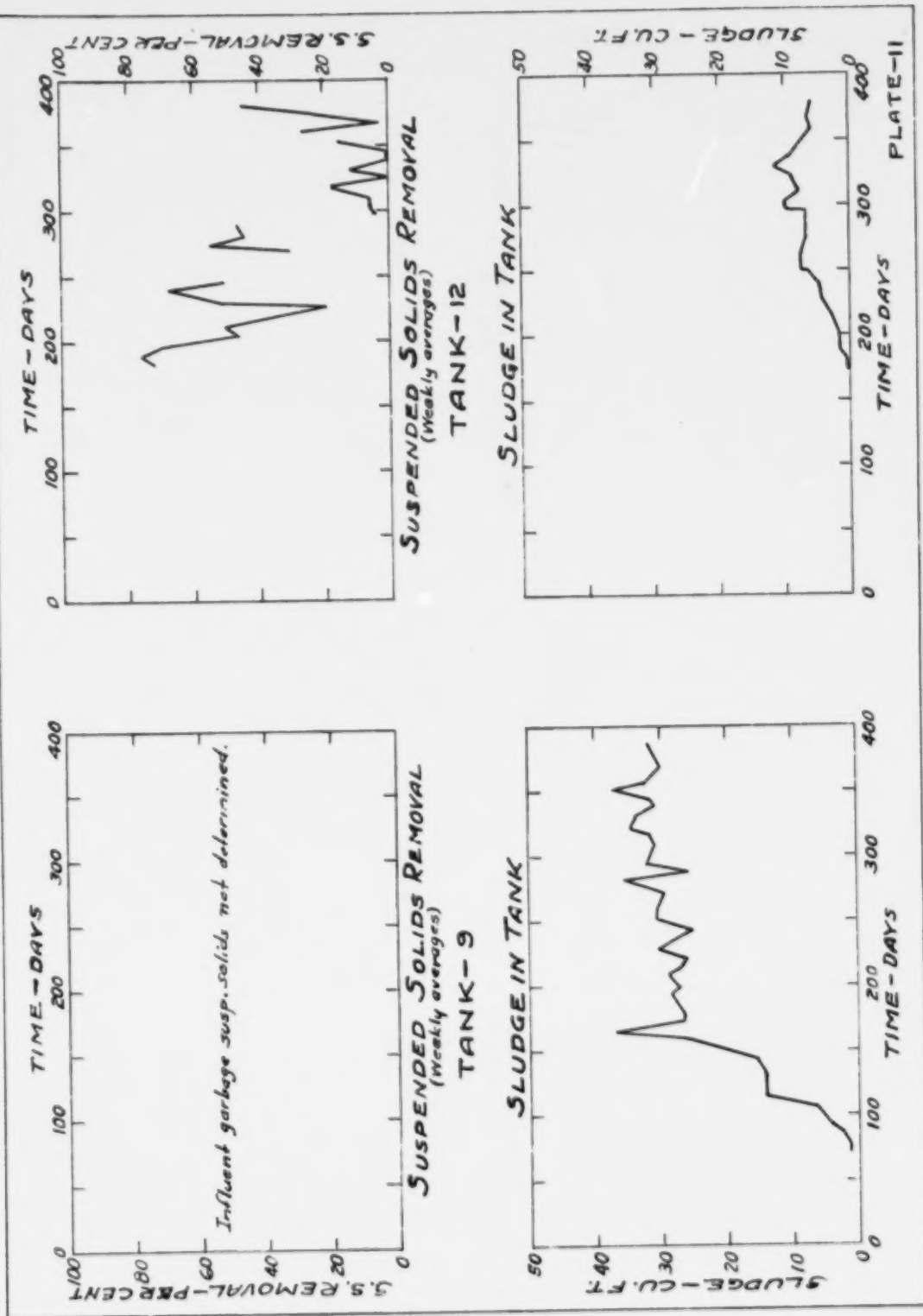
¹December 6 - December 9.

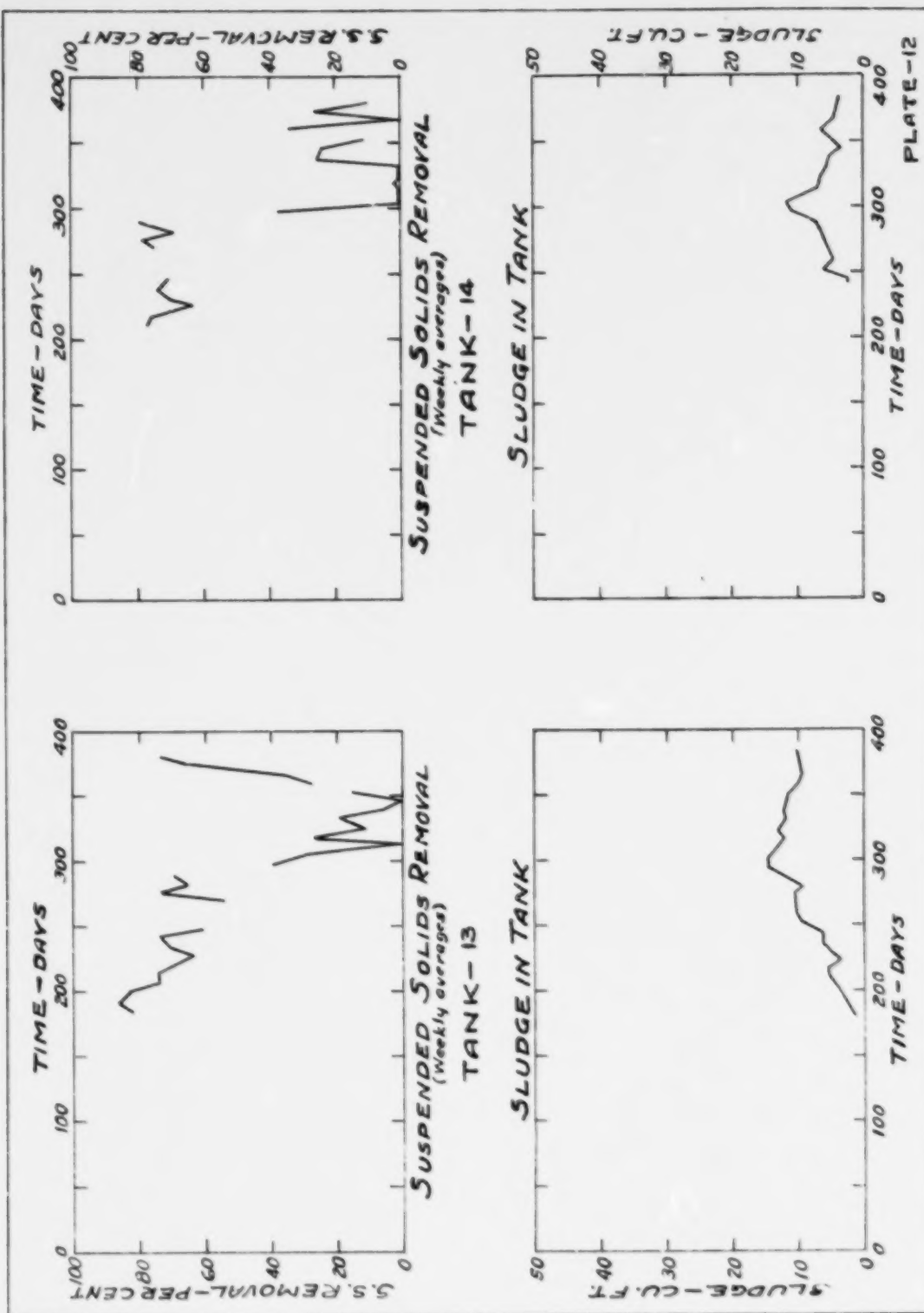












On February 18, 1948, 710 gallons of sludge from a field septic tank were added to tank 1. This large amount of sludge was added to increase the ratio of the sludge volume to tank volume, in order to check whether this ratio would be related to the removal efficiency.

Series V Operation

On February 20, 1948, 37.5 gallons of field sludge were added to tanks 12, 13, and 14. After that date dosing of all tanks was resumed at the previous rate of 250 gallons per day per tank. This constituted the fifth series of operation and extended from February 23 to March 28, 1948. Results are presented in Tables 37, 38 and 42.

This series was relatively significant in that, as noted in Tables 37 and 38, there was a falling off in solids removal efficiency. The only exception to this was tank 4 which showed a suspended solids removal of 89 per cent. Other tank removals were in the order of 40 to 80 per cent. In this series tanks 12, 13, and 14, showed suspended solids removals of 51, 71, and 78 per cent, respectively.

An examination of Plates 7 to 12, inclusive, will show that those tanks which showed low removals in suspended solids also showed that the sludge level in the tank was falling, indicating that sludge was being discharged. This is further corroborated by the increased values given in Table 38 for the standard deviation and the coefficient of variation.

Series VI Operation

The sixth and final series extended from March 30 to June 28, 1948. On March 29, 62.5 gallons of sludge was added to all tanks. During this series, on May 3, four additional tanks were placed in operation, namely, tanks 15, 16, 17, and 18, to study the effect of adding compartments and of decreasing the depth of a Joint Committee type of tank. As in the previous series, sewage was added to each tank at the rate of 250 gallons per day per tank. The results obtained for the 500 gallon single chambered tanks 12, 13 and 14, show very erratic operation as shown in Plates 7 to 12, inclusive, and indicate periodic sludge discharges. In these tanks, the sludge accumulations were decreasing. Sludge was still accumulating in tanks 1, 3, and 4. The results of operation are shown in Tables 37, 38 and 43. Removals in suspended solids varies from -20.3 per cent in tank 8 to 88 per cent in tank 4, the minus value indicating a discharge of sludge. Tank 3 had just about reached its maximum sludge accumulation, because discharges were indicated at relatively frequent intervals. Table 38 shows the high values obtained for the standard deviation and the coefficient of variation for some of the tanks.

Data tabulated for tanks 15, 16 and 17 reveal that, in general, compartmentation was beneficial. Although in keeping with the results obtained for circular compartmented tanks,

TABLE 42.--Sewage and Effluent Characteristics
5th Series. 250 gal./day Feed. February 23 - March 28, 1948

Item	Raw	1	2	3	4	5	6	7	8	9	12	13	14
Raw Sewage Added gallons	6,412.5												
Total Solids p.p.m.	1,128	892	898	781	681	846	824	826	929	767	879	812	767
T. S. Ash p.p.m.	601	587	614	564	509	588	568	576	626	533	568	548	528
T. S. Volatile p.p.m.	527	305	284	217	172	258	256	250	303	234	311	264	239
Suspended Solids p.p.m.	476	195	248	101	53	186	205	173	286	126	243	140	105
S. S. Ash p.p.m.	123	48	111	33	11	69	85	74	127	40	70	34	24
S. S. Volatile p.p.m.	353	147	137	68	42	117	120	99	159	86	173	106	81
Dissolved Solids p.p.m.	652	697	650	680	628	660	619	653	643	641	636	672	662
D. S. Ash p.p.m.	478	539	503	531	498	519	483	502	499	493	498	514	504
D. S. Volatile p.p.m.	174	158	147	149	130	141	136	151	144	148	138	158	158
pH	7.4	7.5	7.5	7.5	7.6	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.4

TABLE 43.--Sewage & Effluent Characteristics
6th Series. 250 gal./day Feed. March 30 to June 28, 1948

Item	Raw	1	2	3	4	5	6	7	8	9	12	13	14	Raw to Flume Tanks ¹				17	18
														15	16	17			
Raw Sewage Added gallons 19,422.5																			
Total Solids	p.p.m.	688	898	749	638	822	832	749	1,156	853	985	922	1,001	915	721	677	656	745	
T. S. Ash	p.p.m.	477	596	520	463	557	542	513	723	552	589	571	600	505	479	477	449	468	
T. S. Volatile	p.p.m.	211	302	229	175	265	290	236	433	301	396	351	401	410	242	230	207	277	
Suspended Solids	p.p.m.	440	80	264	152	51	246	295	160	485	245	395	315	414	378	200	125	103	200
S. S. Ash	p.p.m.	104	25	119	65	17	114	140	68	229	94	146	115	180	97	72	49	37	78
S. S. Volatile	p.p.m.	336	55	145	87	34	132	155	92	256	151	249	200	234	281	128	76	66	122
Dissolved Solids	p.p.m.	573	608	634	597	587	576	537	589	671	608	590	607	587	537	521	552	553	545
D. S. Ash	p.p.m.	444	452	477	455	446	443	402	445	494	458	443	456	420	408	407	398	412	390
D. S. Volatile	p.p.m.	129	156	157	142	141	133	135	144	177	150	147	151	167	129	114	154	141	155
pH		7.4	7.5	7.5	7.6	7.5	7.5	7.6	7.6	7.5	7.4	7.5	7.5	7.3	7.5	7.6	7.6	7.6	7.6
B. O. D.		402	85	-	72	64	89	120	103	-	100	213	145	164	333	110	106	91	108
B. O. D. reduction per cent		79	-	82	84	78	70	64	-	75	47	64	59	-	67	68	73	68	68

¹ Tanks 15, 16, 17, and 18 built in an existing wooden flume were fed independently of tanks on the central dosing system.
See Plate No. 5.

too much weight should not be given to the data presented in the table because the tanks were operated for but a short time, and under structural handicap. Additional work is planned in this connection.

An eleven-day check of the B.O.D. reductions showed removals of 47 to 84 per cent. The greatest removal was accounted for by tank 4 with a 5-day B.O.D. value of 64 p.p.m.

During the course of the investigation, data were collected relative to the color of the effluent from the various tanks. Notations were made as to whether the effluent was dark, medium dark or light. Summarization of these findings is given in Table 44.

Solids Balance

In an effort to obtain some information on the extent of digestion, data were compiled on the pounds of material added to each tank, the pounds of material in the effluent from each tank, the pounds of material removed by each tank during the period of operation, and the pounds of material remaining in the tank upon the cessation of operation. The latter quantity was obtained by thoroughly mixing the tank contents after feeding was discontinued and examining the samples collected.

The results of these computations, however, were highly erratic and no definite conclusions can be drawn from such examination of the data as has been made thus far. Further examination will be made. In future studies it may be desirable to check the progress of digestion from time to time and to follow this progress without interference of sludge additions.

Sludge and Scum Accumulations

Scum and sludge measurements were made at the start of each week of operation. Sludge sounding and scum measuring rods similar to the type developed for field use were utilized and have been described previously. These are shown in Appendix D.

Scum measurements were made at the influent and effluent ends of the tanks, and sludge measurements were made at several points in all tanks. The number of points selected was dependent upon the size and shape of the tank, and varied from a minimum of one reading for each unit of the multichambered tanks to nine for the single chambered tanks.

Scum and sludge volumes covering the entire period of operation to date are given in Tables 79 and 80 in Appendix C. Sludge volumes for each tank are shown graphically in Plates 7 to 12, inclusive. Sludge volumes are only relative since the compactness of the sludge is not known. Actually the sludge in the tanks is a fluid type of sludge and is not compact.

Chemical examination of the total solids and volatile contents of the scum and sludge have been made at various intervals of time. These results are presented in Tables 45 and 46, respectively.

Plates 7 to 12, inclusive, also show the relationship between sludge volume and efficiency as measured by the removal of suspended solids in each tank. In most cases, it will be noted, that the efficiency increases as the sludge level increases to a certain optimum value. As more sludge is added either in the form of sewage or field septic tank sludge a reduction in the apparent volume of sludge appears to occur, and at the same time the tank efficiency falls off. This point of maximum sludge accumulations was taken as the point of maximum sludge retention by the particular tank in question. Thus, the point of sludge discharge may be selected for the 12 basic tanks (tanks 1 to 9 and 12 to 14, inclusive) which are discharging sludge. Tanks 1, 4, and 9, had not reached peak sludge accumulation at the time the project was discontinued.

In Tables 47 and 48 the time required to accumulate the maximum sludge volume has been computed from data obtained from observations of field tanks and presented in Plate 18. Two sets of values are presented in Tables 47 and 48, the first of which is computed from a consideration that the sludge volumes measured in the greenhouse tanks may be compared

TABLE 44.--Color of Effluents, Percentage Basis

D - Dark
M - Medium
L - Light

Series	Color	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
I	D	7.9	3.3	8.3	8.3	6.4	6.2	4.4	3.3										
	M	9.6	10.4	10.0	10.6	10.6	20.3	11.2	12.1										
	L	82.5	86.2	81.7	81.2	83.0	73.5	84.4	84.6										
II	D	2.5	5.4	5.8	6.3	5.0	9.2	6.3	5.8	9.0	6.1	8.6							
	M	2.1	6.7	7.5	6.3	3.8	6.7	5.4	6.3	7.2	2.6	3.4							
	L	95.4	87.9	86.7	87.3	91.3	84.2	86.3	87.9	85.1	91.3	88.0							
III	D	1.4	2.3	0.9	0.9	3.8	2.4	1.4	1.9	14.8	7.1	5.7							
	M	2.4	9.4	4.2	0	13.2	13.7	5.2	16.6	33.0	9.2	6.4							
	L	96.2	88.3	94.8	99.1	83.0	83.9	93.4	81.5	57.1	83.7	87.9							
IV	D	1.4	3.8	1.8	1.7	2.1	2.0	3.0	2.6	2.1			0.4	0.2	0.3				
	M	1.5	2.8	1.9	1.2	2.6	1.2	3.5	1.9	3.4			0.8	1.6	0				
	L	97.1	93.4	96.3	97.1	95.3	96.8	93.6	95.6	94.5			98.8	98.1	99.7				
V	D	26.9	7.5	4.3	0	6.9	3.2	6.9	10.8	10.3			2.5	0.6	0				
	M	31.3	12.4	6.2	0.6	8.8	14.8	11.3	6.3	18.0			1.2	2.4	0				
	L	41.9	80.1	89.4	99.4	84.4	81.9	81.8	82.9	65.2			96.3	96.9	100				
VI	D	0.6	4.9	2.8	0.3	4.1	11.7	3.4	13.1	6.4			4.2	4.5	12.7	3.6	0.3	2.1	0.6
	M	4.7	6.8	2.3	3.4	5.8	7.9	6.2	11.0	12.6			47.0	67.1	63.7	15.5	7.5	19.8	5.1
	L	94.7	88.3	95.0	96.3	90.1	80.4	90.4	75.9	79.4			48.8	28.8	23.7	83.9	89.2	78.1	94.3

TABLE 45.--Scum Solids Analyses

Total Solids, Percent				Volatile Solids, Percent										
Tank/Dates	6/25	7/8	7/22	8/5	8/19	9/3	9/17	6/25	7/8	7/22	8/5	8/19	9/3	9/17
1	9.9	--	--	--	--	--	--	68.5	--	--	--	--	--	--
2	9.7	12.7	12.6	11.6	10.5	--	--	61.3	57.0	52.9	56.0	52.3	--	--
3a ¹	8.7	8.1	9.7	12.5	16.9	16.9	7.2	59.8	62.1	66.0	60.5	57.4	53.7	53.3
4a ¹	9.6	12.0	15.4	17.4	19.5	17.1	12.4	60.1	66.2	65.1	61.4	57.8	56.6	56.5
4b ¹	--	11.1	--	--	--	17.4	11.9	--	58.6	--	--	--	41.2	46.5
5	9.7	13.2	8.7	11.6	8.0	--	--	59.8	56.3	59.7	58.7	58.0	--	--
6	10.6	12.6	9.9	11.9	10.2	--	--	58.6	56.3	56.0	55.2	53.4	--	--
7	11.3	13.2	8.2	10.3	7.9	--	--	55.2	57.0	53.9	56.6	54.8	--	--
8	9.9	14.0	11.9	11.4	9.5	--	--	60.4	54.6	53.0	53.3	51.2	--	--
9	--	--	--	--	--	9.5	8.3	--	--	--	--	--	56.4	74.5
10	--	--	--	--	--	--	10.1	--	--	--	--	--	--	57.2
11	--	--	--	--	--	--	--	--	--	--	--	--	--	--

¹Respective compartments of multichambered tanks.

TABLE 46.--Sludge Solids Analyses

Tank	Total Solids, Per cent		Volatile Solids, Per cent	
	Date, 1947		Date, 1947	
	August 9	September 10	August 9	September 10
1	7.7		48.9	
2	9.1	8.1	48.1	47.6
3a ¹	7.6	7.2	39.5	54.3
3b ¹	8.5	6.8	48.3	49.1
4a ¹		7.4		49.0
4b ¹		7.5		58.7
4c ¹		7.5		46.3
5	7.2	6.8	47.8	52.6
6	9.4		50.4	
7	5.1		48.4	
8	7.5		51.2	

¹Respective compartments of multichambered tanks.

TABLE 47.--Estimated Years Tank Operation Based on Sludge Accumulations in Tanks¹

Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
I 8/19/47	2	1-	1-	1-	1-	1-	1-	1-										
II 9/17/47	3	1-	1-	1-	1-	1-	1-	1-	1-	1-	1-							
III 11/6/47	7+	3-	3+	5-	4-	3-	6+	1	2+	1-	1-							
IV 2/16/48	13+	4	6+	8-	6-	4-	5+	3	5			1-	1-					
V 3/29/48	17+	3	6	8	6+	4	5+	2-	5+			1-	1-	1-				
VI 6/28/48	20+	1+	8	9+	6+	4-	6-	1	7			1-	1-	1-				
Peak	20+	4-	8	9+	8-	7	7	4	8	1-	1-	1-	2-	1-				
Peak comp a			5-	1+									1-	1-				
Peak comp atb			8	5									2-	1-				
Peak comp atbic				9-														
Peak comp atbtctd				9+														

¹Using sludge data only on curve drawn from field observation.

TABLE 48.--Estimated Years Tank Operation Based on Sludge and Scum Accumulations in Tanks¹

Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
I 8/19/47	1-	1-	1-	1-	1-	1-	1-	1-										
II 9/17/47	2-	1-	1-	1-	1-	1-	1-	1-	1-	1-	1-							
III 11/6/47	5-	2-	2-	3-	2+	1+	4-	1-	1-	1-	1-							
IV 2/16/48	9-	2	4-	5-	3	2	3	1+	3			1-	1-	1-				
V 3/29/48	13-	2-	3+	5-	4	2+	3	1-	3			1-	1-	1-				
VI 6/28/48	13+	1-	5	6+	4-	2-	3+	1-	4+			1-	1-	1-				

¹Using sludge and scum data on curve drawn from field observations.

with the sludge data given in Plate 18; and the second, that as the greenhouse tanks overturned at rather frequent intervals, the sludge volumes measured represent a mixture of scum and sludge and are compared with the sludge plus scum curve on Plate 18, representing total scum and sludge accumulation.

B.O.D. Removals

All the biochemical oxygen demand data collected during the investigation on household septic tank is summarized in Table 49. These results indicate that, in general, B.O.D. removals increase with sludge accumulation through the fourth series of operation. This coincides approximately with the periods of maximum sludge concentrations in the single chambered tanks under observation at that time. There was a slight additional increase in efficiency in the multi-chambered tanks as shown by the results given for the sixth series. When the tanks are operating below maximum sludge capacity removals in the order of 65 to 84 per cent may be expected.

The B.O.D. values and removals have been discussed more fully previously.

Sulfides

To note the variation in sulfide ions content of the various tanks and its possible corrosion influence, studies were instituted to determine the concentration of sulfide ions present. Samples were siphoned from the effluent ends of the tanks to prevent aeration and the consequent reduction of sulfide ions present.

Preliminary tests, the results of which are given in Table 50, indicated, for the period August 8-19, 1947, when 7 grab samples were taken at various times, that the single-chambered tanks and the final chamber of the multi-chambered tanks had approximately the same concentration of sulfide ions present. These data also show that the sulfide ions concentration increases progressively from the first to last chamber. This may possibly be explained, as will be seen later, by the fact that dilution with fresh sludge would tend to reduce the concentration in the first compartments and that these diluted mixtures then pass on to the following compartment until a maximum value is reached in the final compartment. The time of sampling has a significant effect upon the results obtained because the raw feed did not contain detectable sulfides.

The hourly variation in sulfide ions on October 28-29, 1947, is shown for tank 7 in Plate 13, and the hourly variation for each compartment of the 4-compartment tank 4 on November 5-6, 1947 is shown in Plate 14. The dilution effect of the feed sewage is clearly indicated in both figures. Average curves have also been prepared showing sulfide ions concentrations in each compartment during or immediately after feeding and during periods of quiescence, and are shown in Plate 14. The very high value indicated (132 p.p.m.) for the sulfide ions content at 3:30 p.m. October 28, may possibly be due to the fact that the sample was taken shortly after a turnover of the tank contents had occurred.

To note the effect of a relatively long period of quiescence (94 hours) on sulfide ions concentration, samples were collected from all the tanks on November 12. These results are given in Table 50 under the appropriate date. In general, the results are somewhat higher than those previously reported.

There seemed to be little difference in the sulfide ions concentrations of the various tanks, with the exceptions noted due to compartmentation. High sulfide ion concentrations are conducive to corrosion and have been discussed by several authorities (indicate work of Pomeroy, et al) and where tanks are not properly protected either by means of a protective coating or cathodically, corrosion will in all probability take place.

To show the difference in hydrogen sulfide production in open and closed containers, two flasks were set up; one, the closed unit, contained 9,700 milliliters of fresh sewage and was connected to a gas collecting unit, and the other, the open unit, contained 500 milliliters of fresh sewage in an open flask. The results obtained are plotted in Plate 15 and show that more sulfides were present in the closed flask than the open flask.

Ammonia Determinations

Ammonia was determined to note what difference might be present in the various tank effluents. Two series of tests were made and these are shown in Table 51. A study of these data indicates that with the possible exception of tanks 12, 13 and 14 which had a short determination, there was little difference in the ammonia content of the effluents.

TABLE 49.--B.O.D. of Sewage and Tank Effluents

		5-day B.O.D., p.p.m.																				
		Raw	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	RR ²	
Series 1 Aug. 12-15		370	175	240	177	146	202	210	214	213												
2 Sept. 8-19		362	147	166	172	146	162	160	176	185	256	213	222									
3 Oct. 23-29		366	94	128	85	66	85	84	99	100	92	93	84									
4 Dec. 3-9		480	144	130	137	131	134	127	114	124	112											268 ¹ 230 ¹
6 June 9-19		402	85	-	72	64	89	120	103	-	100											213 146 164 110 106 91 108 333
¹ Dec. 6-Dec. 9																						
² P.R. - Refers to raw sewage fed tanks 15, 16, 17 and 18																						
																					Reduction, Percent	
Series 1 Aug. 12-15		-	53	35	52	61	45	43	42	42												
2 Sept. 8-19		-	59	54	52	60	55	56	51	49	29	41	39									
3 Oct. 23-29		-	74	65	77	82	77	77	73	73	75	75	77									
4 Dec. 3-9		-	70	73	71	73	72	74	76	74	77											44 52
6 Jun. 9-19		-	75	-	82	84	78	70	64	-	75											47 64 59 67 68 73 68 -

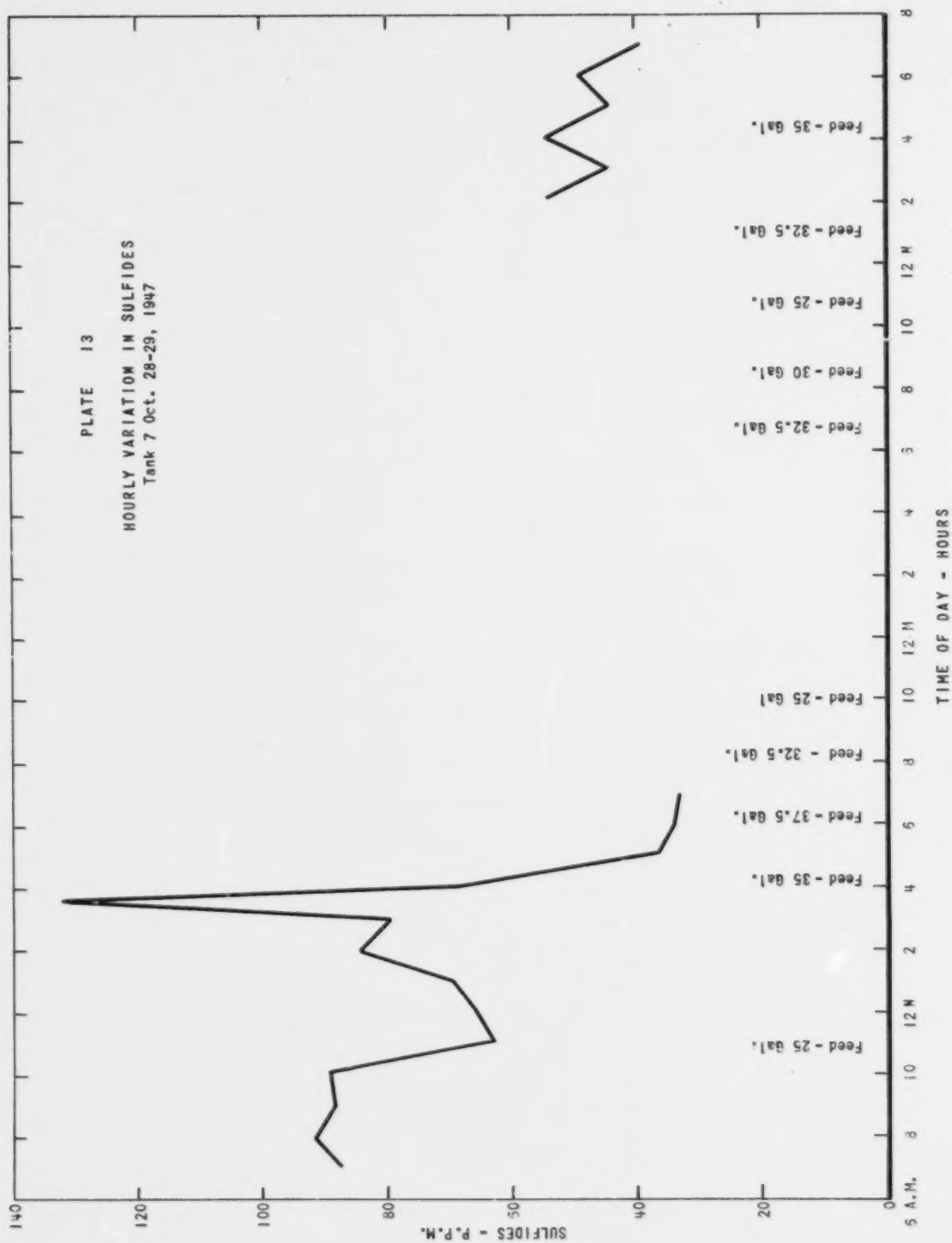
TABLE 50.--Sulfide Test Results

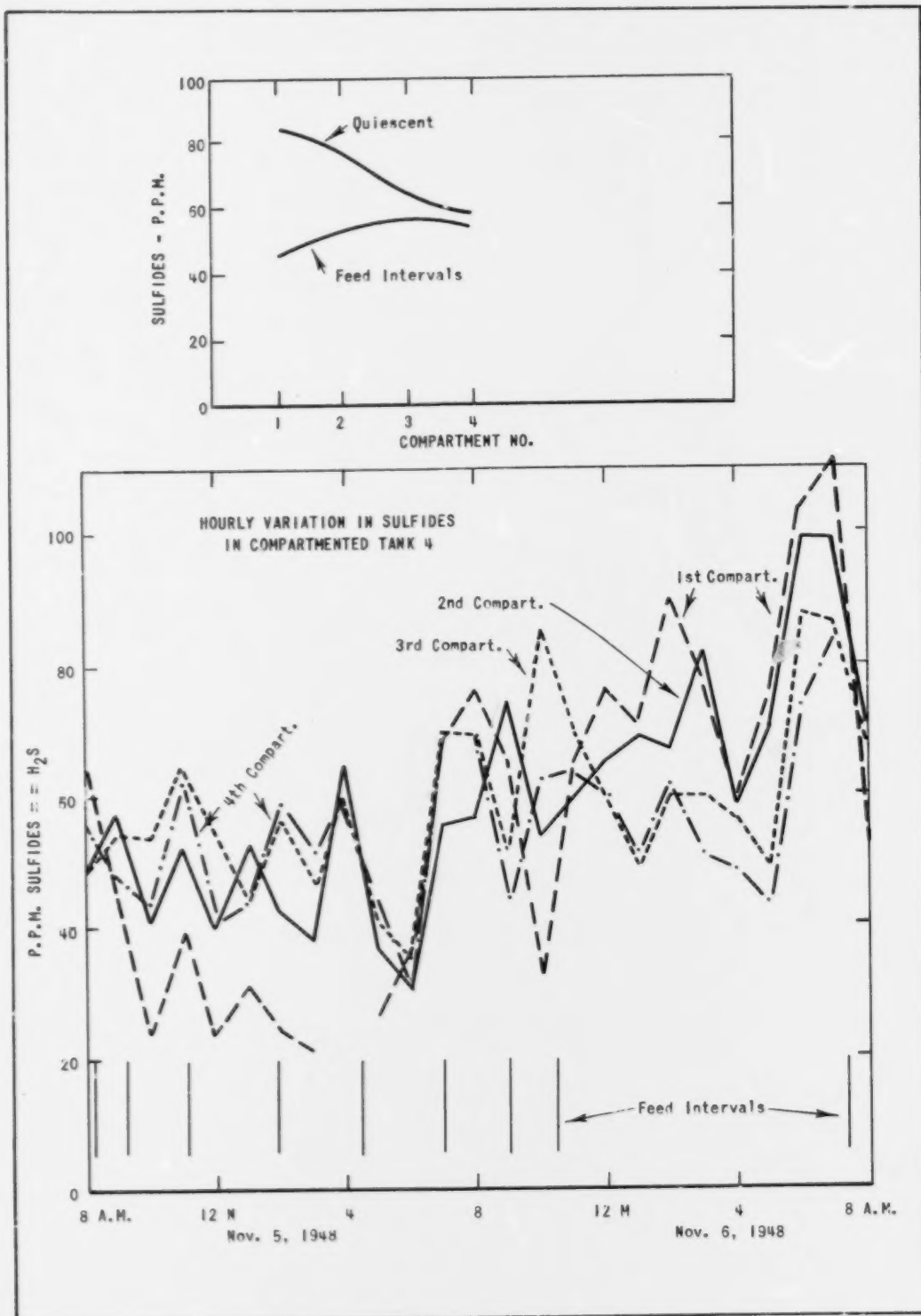
Tank	August 8-19, 1947		September 9-26, 1947		November 12, 1947		December 17, 1947		February 6, 1948	
	No. obs.	Results Av. p.p.m.	No. obs.	Results Av. p.p.m.	No. obs.	Results p.p.m.	No. obs.	Results p.p.m.	No. obs.	Results p.p.m.
1	7	54	10	29	1	56	1	51		
2	7	55	10	43	1	49	1	64		
3-a	7	25	10	49	1	67	1	28		
3-b	6	49	10	47	1	52	1	47		
4-a	6	21	10	50	1	57	1	25	1	7
4-b	7	38	10	54	1	51	1	42	1	19
4-c	6	50	10	53	1	49	1	48	1	27
4-d	6	54	10	45	1	52	1	39	1	1
5	7	53	10	50	1	77	1	62		
6	7	54	10	47	1	53	1	55		
7	7	56	10	38	1	86	1	60		
8	7	52	10	46	1	77	1	68		
9			10	52	1	92	1	85		
10			10	43						
11			10	43						
Raw Sewage	7	0	5	0			1	0		
12							1	0	1	1
13-a							1	Tr	1	Tr
13-b							1	Tr	1	3.2
14-a									1	0
14-b									1	1
14-c									1	1

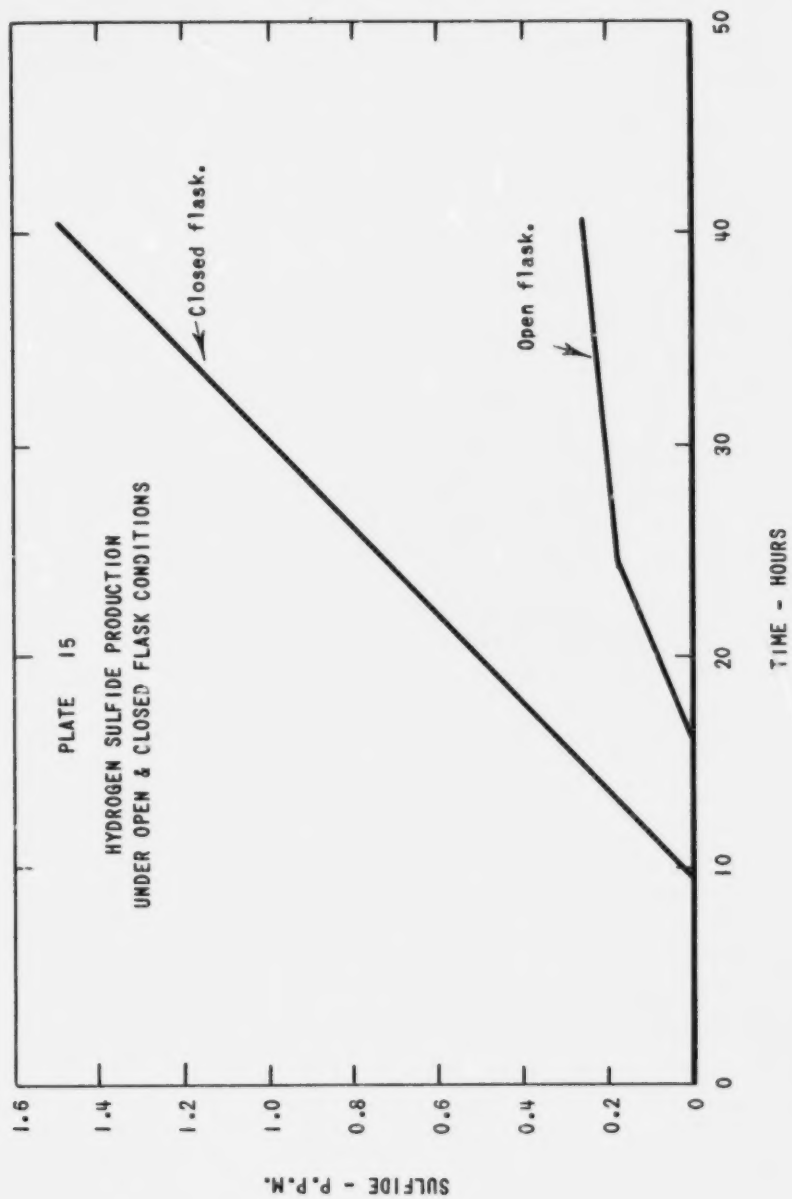
TABLE 51.--Ammonia Nitrogen Determinations

Tank	Date of Determinations	
	February 12-13	February 17-18
	p.p.m.	p.p.m.
Raw sewage fed	8	26
1	36	36
2		34
3-a		
3-b		32
4-a		26
4-b		34
4-c		38
4-d	34	38
5		32
6		38
7	32	
8		34
9	32	
12	16	32
13	24	30
14		30

Soil scientists believe that the presence of ammonia in the sewage effluents may produce HNO_3 in the soil which will disperse (break the soil up into finer particles) thus filling the soil pores and causing clogging.







Grease

Grease determinations were made on several samples of effluent from each tank and the raw sewage. Duplicate tests were made on the grab samples which were collected directly from the tanks by means of a siphon. Single tests were made on the composite samples which were composited from the effluent collected in the effluent barrels after each feed. The samples were composited on the basis of volume. Effluent samples were collected for grease determination to obtain some preliminary information on how effective septic tanks are in the removal of grease, and as a result, whether grease traps are a necessary part of the septic tank system.

As indicated by the results given in Tables 40 and 52, removals in the order of 71-92 per cent were obtained.

In a theoretical discussion of gravitational separation of grease in grease Interceptors, F. M. Dawson, A. A. Kalinske, *Sewage Works Journal*, 16:3, 482-489 (May, 1944) state that ".... the average efficiency for the rate of flow at which an interceptor is rated and for its special grease-retaining capacity should not drop below 90 per cent." They further report that the use of grease interceptors on kitchen sinks is of debatable significance because the small amount of grease usually discharged in kitchen sinks are so mixed with soaps, washing compounds, and food wastes, that gravity separation in a grease interceptor is practically impossible. The success of any grease trap is dependent wholly upon public cooperation and the disposal of grease interceptor contents is a definite nuisance.

TABLE 52.--Results of Grease Determinations By Tanks

Tank	No. of tests		Results in p.p.m.	
	Grab	Composite	Grab samples	Composite samples
1	1	2	37.5	17.6, 2.2
2	1	2	37.9	9.9, 16.0
3	1	2	41.1	3.7, 11.7
4	1	2	33.5	11.0, 12.5
5	1	2	37.6	16.0, 22.2
6	1	2	23.6	9.4, 33.0
7	--	2	--	12.1, 32.1
8	1	2	30.3	12.3, 45.5
9	-	2	--	15.7, 38.9
10	1	2	40.1	19.3, 33.8
11	1	2	46.7	29.8, 41.1
Raw sewage	--	15	--	102.9, 83.3, 113.7, 160.5, 172.8, 32.3, 96.1, 77.5, 63.6, 96.4, 129.3, 164.4, 84.5, 59.6 and 60.1
Septic tank sludge	1		5,850	--
Imhoff tank sludge	1		4,854	--

Raw Sewage Results, According to Day of Week

Day of week	No. of tests	Results of composite samples	
		Individual tests	Average
Monday	2	96.1, 59.6	77.8
Tuesday	2	77.5, 60.1	68.8
Wednesday	2	113.7, 63.6	88.6
Thursday	2	160.5, 96.4	128.4
Friday	3	83.3, 172.8, 129.3	128.5
Saturday	1	164.4	164.4
Sunday	3	102.9, 32.3, 84.5	73.2

In studies reported by these same authors, they found that a 90 per cent removal of grease was possible. However, the concentration of grease in their test mixture was in the order of 2.4 per cent by weight. It is a well known fact that the smaller the quantity of a substance there is present in the mixture the more difficult it is to remove. In the raw sewage coming into the Station the concentration of grease was in the order of 100 parts per million, whereas even with a removal efficiency of 90 per cent as indicated by the Dawson & Kalinske tests, the effluent from their grease interceptor would have a grease concentration of approximately 2,400 p.p.m.

If the reasons cited above are insufficient for discontinuing the use of grease traps on septic tank systems, then the fact that the septic tank being so much larger than the grease trap offers, in addition to longer detention times, the advantage of increased storage for removed grease, and the elimination of the human factor in the satisfactory maintenance of grease traps.

Chlorides

Some determinations were made of the normal chloride concentration of raw sewage at various times during the day. It was presumed that if sufficiently wide differences were detected in the hourly chloride content of the raw sewage, these differences might also appear in the effluent from the septic tanks. Explanatory studies were made by sampling the raw sewage at hourly intervals and determining the concentration of chlorides as sodium chlorides. Results obtained on three separate days are shown in Plate 16. At the same time, tests were also made of the concentration of chloride as sodium chloride in the raw sewage fed to the tanks prior to each feed, and also of the effluent samples collected following each feed. These results are shown in Plate 17, and indicate that, on the day in question, the lowest salt concentration in the raw sewage occurred at the first feed and increased throughout the day until evening, at which time it dropped again. The effluent from tanks 4 and 7 were high in chlorides early in the morning, remained high until 4:30 in the afternoon for tank 7 and then dropped rapidly, rising again in the evening. Tank 4, however, continued high and relatively constant until 10:30 and dropped rapidly after that feed.

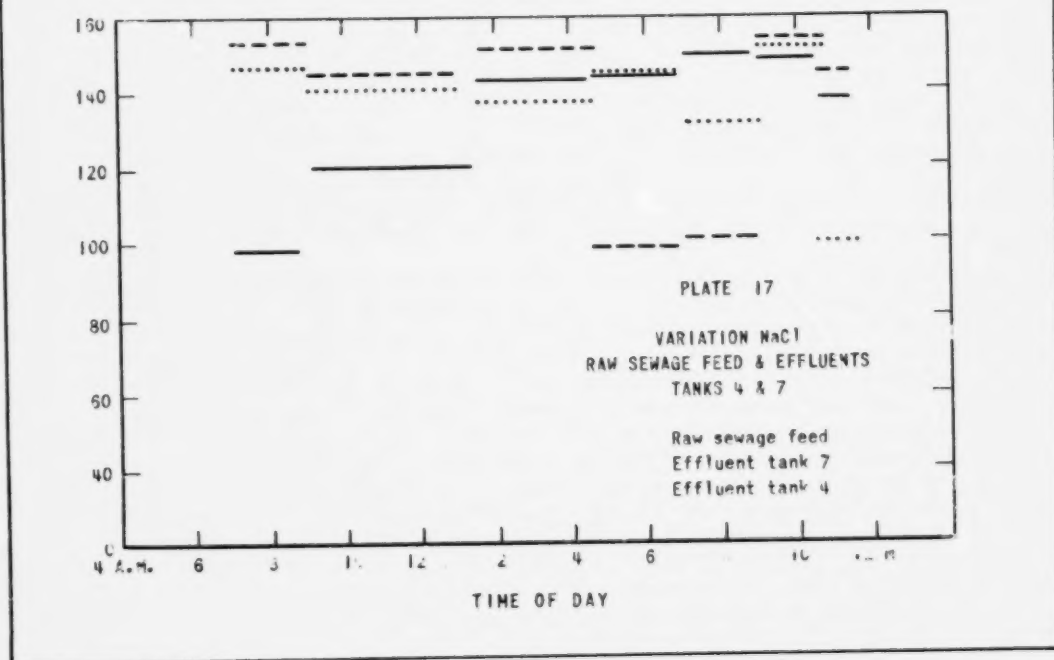
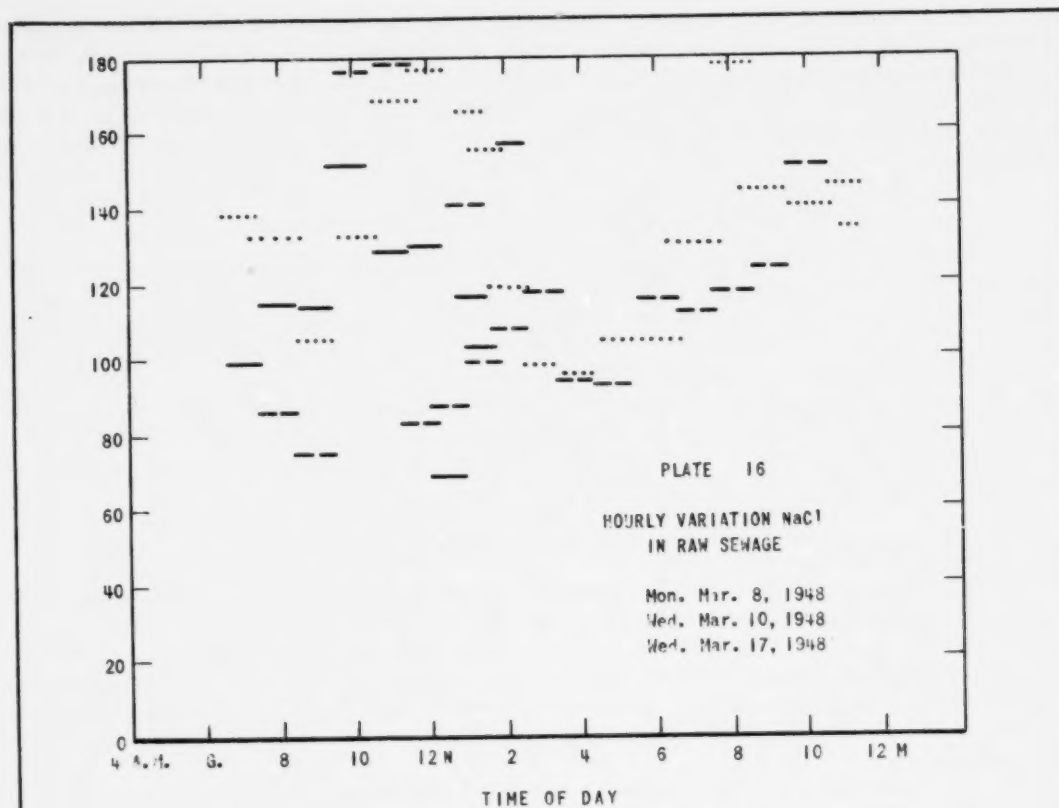
These studies indicate that the normal salt concentration may be used to determine an approximate time of detention in the tanks, without the disadvantages claimed for the use of added slugs of salt because of increased specific gravity. Due to a reduction in personnel, no more work on this problem could be undertaken.

Inlet and Outlet Studies

On August 20, 1947, two tanks were set up in the wooden flume, in the position of tanks 15 and 16 (shown in the right half of Plate 5). These tanks were numbered 10 and 11. Tank 10 was similar to the 500-gallon Joint Committee tank number 7 and served as a control. Tank 11 was similar in volume, but the outlet was modified. In place of the standard outlet an effluent weir was provided across the full width of the tank about 6 inches out from the effluent end of the tank. To prevent the discharge of scum, a 24-inch baffle extending 16 inches below the surface of the tank was placed across the tank 12 inches back from the effluent end of the tank.

A summary of the data is presented in Table 37, 39 and 40, and a statistical summary is given in Table 38. A study of these data indicate that there was no significant difference in the type of effluent discharged by either tank. However, as indicated by the standard deviations and the coefficients of variation, the results of tank 11 (the one with the weir type of outlet) were more uniform than for tank 10, although the actual removals in the latter were slightly higher than in the former.

A minor modification in the design of tank 11 might have shown some advantage for that type of tank. Due to the overturning of the tank contents, there were times when sludge would be washed over the weir and would accumulate between the weir plate and the outlet



shelf. The inclusion of another baffle extending from the bottom of the tank at an angle beyond the vertical baffle would have diverted the rising sludge and kept it behind the vertical baffle thus preventing its discharge over the weir. Sludge was not discharged to the same extent in tank 10 because the standard tee outlet has a relatively small area, and the tee itself, since it extends above the level of the tank, prevents material from passing into the outlet.

Introduction of Influent Sewage Through Sludge

To study the effect of modifying the inlet to feed into the sludge level, two small model septic tanks were built and observed for a short period in the laboratory. In one of the units the inlet was carried into the sludge level and in the other a normal type of inlet was provided. The results obtained were inconclusive. In the first place, some of the sludge from the bottom fed tank was lost, thus modifying the conditions of test, and in the second place, the shape and length of the inlet tube in this tank was such that it extended more than half way across the tank bottom. A diverting baffle should have been provided. Large tanks should be used when these tests are repeated because of the difficulty of translating the hydraulic properties of prototype to model.

Effect of Compartmentation

As has been pointed out earlier, particularly in the discussion of the results of the first series, the two tanks 3 and 4, produced an effluent which was considerably better than that for any of the other tanks in the same capacity range. These tanks have produced a satisfactory effluent with the lowest solids content of any of the tanks almost throughout the entire study. Since the primary difference between these tanks and the others has been compartmentation and the greater depth, these two factors alone are probably solely responsible for this difference.

In all tanks having compartments (3 and 4, 13 and 14, 16 and 17), greater removals were recorded than in single chambered tanks during their periods of effective operation. Tanks 13 and 14 were rather short-lived, on the basis of sludge accumulations, as compared to the other tanks, but this is due to the fact that these tanks were of smaller capacity; 246 gallons and 289 gallons, respectively.

Until the sludge accumulates beyond a certain point in the respective tanks, depth does not appear to be too significant a factor in the initial operation of the tank. As evidence the early results obtained for tank 14 may be cited. Removals in suspended solids in the order of 71-78 per cent are given. In fact, in the fifth series, tank 14 with a liquid depth of 18 inches showed higher removal than did tank 13 which had a liquid depth of 5 feet, 3 inches. It was shortly after this period, due to the addition of sludge, that the sludge retaining capacity of tank 13 and 14 was reached and removal efficiencies dropped. The drop in tank 14 was greater than in tank 13 and it may be here that the depth factor exerted some influence.

Compartmentation may have a further effect on increasing removal efficiencies in that the division of a tank into smaller cells or compartments tends to concentrate more of the sludge in the first compartments or near the influent end, than would be the case with single chambered units of the same size as the total capacity of the compartmented unit. This greater accumulation of a more fluid sludge may serve as in inoculating medium for the incoming sewage, thus increasing the removal through flocculation and surface absorption. Even though these larger masses may be carried over into subsequent chambers the periods of quiescence following feeds would afford an opportunity for increased sedimentation.

The discharge of relatively large volumes of sewage (up to 22.5 per cent of the compartment volume in the case of tank 4) might be sufficient to stir up the tank contents, thus increasing the apparent sludge volume. That this does not take place is indicated by the results given in Table 53 which shows the percentage increase in apparent volume in each compartment of tank 4. The greatest increase in apparent tank volume in the first compartment was 8 per cent; in the second, 24 per cent; in the third, 45 per cent; and in the fourth, 4 per cent. Sludge readings were made 30 seconds after the completion of the feed.

TABLE 53.--Apparent Sludge Volume After Tank Feed - Per Cent - Tank 4-Ts¹

Compartments	February 16			February 17			February 18			February 19			February 20		
	7 a.m.	9 a.m.	11 a.m.	1:30 p.m.	9 a.m.	11 a.m.	7 a.m.	9 a.m.	1:30 p.m.	7 a.m.	9 a.m.	11 a.m.	1:30 p.m.	4:30 p.m.	9 a.m.
1	100	99	96	101	103	105	105	103	104	106	108	105	102	105	101
2	99	98	98	124	104	105	104	102	101	107	104	103	100	98	101
3	103	100	100	102	104	99	102	100	101	99	145	122	115	108	108
4	99	96	96	96	101	94	99	104	99	100	100	102	97	96	96

¹The 100 per cent base values for each of the days concerned in this examination were estimated by interpolation between the sludge volumes measured February 16 and February 24, in connection with the weekly routine measurement of acum and sludge (Tables 79 and 80 Appendix C).

The results given for the flume compartment tanks 16 and 17, indicate that in rectangular tanks compartments also have a beneficial effect. However, since these results are based on only several weeks observation, they should not be given too much weight. These runs should be repeated using tanks that do not have the structural limitations that the flume tanks studied had.

Summary

1. Eighteen full sized septic tanks representing a variety of shapes and sizes were compared, under parallel operating conditions, on the basis of solids removal for periods up to a year. The eighteen tanks are identified as follows:

Tank number	Description	Total liquid capacity (gallons)	Tank number	Description	Total liquid capacity (gallons)
1	Jt. Comm., Rect.	2,060	10	Jt. Comm., Rect. (Tee Outlet)	539
2	Round End	513	11	Jt. Comm., Rect. (Weir Outlet)	539
3	2-36 inch Dia. Vert. Cyl. in Series	553	12	24 inch Dia. Vert. Cyl.	123
4	4-24 inch Dia. Vert. Cyl. in Series	673	13	2-24 inch Dia. Vert. Cyl. in Series	246
5	Oval	525	14	24 inch Dia. Hor. Cyl. (3 Comp.)	289
6	52 inch Dia. Vert. Cyl.	455	15	Jt. Comm., Rect.	539
7	Jt. Comm., Rect.	539	16	2 Comp. Rect.	539
8	52 inch Dia. Hor. Cyl.	492	17	3 Comp. Rect.	539
9	Jt. Comm., Rect. (Garbage & Sew.)	539	18	Rect.-3 foot Depth	405

2. The tanks were dosed 8 times a day from 7 a.m. to 10:30 p.m. from a central feed tank. Combined sewage from a residential section of Cincinnati was used. Following seeding of the tanks, an initial run was made at 500 g.p.d. (most tanks were about 500 gallon capacity), after which the dosage was reduced to 250 gallons per day. Sludge accumulation was accelerated by adding sludge obtained from septic tank cleaners. Samples composited from all doses were examined routinely for solids, occasionally for B.O.D., sulfides, grease, ammonia and chlorides.

3. An initial run was made with 8 tanks at a dosage of 500 gallons per day each, after seeding, during which the efficiencies of suspended solids removal ranged from 16 to 60 per cent for the various tanks, tanks 1, 3 and 4 having the highest efficiencies, 60, 59 and 56 per cent respectively. The subsequent reduction of dosage to 250 gallons per day resulted in higher efficiencies for all tanks and narrowed the spread in efficiencies, the range being 53 to 76 per cent. Following this run, four successive runs were made, each preceded by the addition of quantities of sludge to each of the tanks, to enable the determination of efficiencies over a range of sludge accumulations equivalent to from 1 to over 9 years of service.

4. Other tanks were added to the original 8 at various times during the year's study, some of which received a short period of operation up to the time of suspension of the Project in June, 1948. Further operation of these is intended when the Project becomes active again.

5. Comparison of tank shapes and sizes on the basis of suspended solids reduction revealed considerable difference in the operating efficiencies of the tanks. Tank 4 showed highest efficiency. At relatively the same order of efficiency were tanks 1 and 3. The 5 single compartment tanks in the 500 gallon size gave overall efficiencies of about the same magnitude during their useful period although there were differences in the individual runs, and considerable difference in normal operating life (point at which sludge discharges) indicated by the sludge accumulations. Circular shapes in series, ineffect, compartmentation,

consistently provided a higher degree of suspended solids reduction than any of the single compartment of about the same capacity.

6. Three runs on a 24-inch diameter vertical cylindrical tank of 123 gallons capacity; two such tanks in series, totaling 246 gallons capacity; and a 24-inch diameter horizontal cylindrical, 3 compartment tank of 289 gallons capacity, indicated a fairly high percentage removal of suspended solids, and particularly so considering that they were dosed at 250 gallons per day. However, their normal operating life appeared to be very short as compared to the 500 gallon tanks.

7. A single run on a battery of 4 rectangular tanks of single, double and triple compartments, and a shallow single compartment rectangular tank, was beset with leakage troubles and the results, though shown, are not considered too significant. Additional investigation is intended.

8. Apparent improvement in solids reduction efficiency as sludge accumulations increase to some point, indicates the desirability of investigating the introduction of influent through the sludge.

9. Grease removals of 71 to 92 per cent were obtained during the experimental runs. The raw sewage grease concentration was about 100 p.p.m., which is fairly representative of municipal sewage.

10. Experimental comparison of a standard Tee outlet with a baffled weir outlet on a 500 gallon Joint Committee type tank revealed no significant difference in effluent quality.

11. Tables of estimated years of tank operation based upon sludge, and sludge plus scum accumulations, indicate considerable difference in the solids retaining capacities of the various tanks.

SECTION D

STUDY OF SEPTIC TANKS IN FIELD
SLUDGE AND SCUM ACCUMULATIONS

STUDY OF SEPTIC TANKS IN FIELD, SLUDGE AND SCUM ACCUMULATIONS

Introduction

A total of 300 single household type septic tanks in normal operation in nine areas over the country were examined and reported by two-man engineer-laborer teams during the period February, 1947 to July, 1948.

Geographical Distribution Inspections

The installations inspected were geographically distributed as indicated in Table 54. These represent but a fraction of the many hundreds of house-to-house contacts which were made in order to obtain installations which had not been cleaned too recently, for which household history was available, and for which permission to excavate and examine could be obtained. In some cases inspections had to be abandoned after excavating, because of a solid roof without access manholes.

TABLE 54.--Distribution of Inspections by Survey Areas

Area No.	Location	Total Number of Inspections
1	Dallas	15
2	Kansas City	92
3	Cook County, Ill.	45
4	St. Joseph, Ind.	34
5	Cincinnati	42
6	Kalamazoo, Mich.	10
7	Warwick Co., Va.	34
8	Cuyahoga Co., O.	0 ¹
9	Montgomery Co., Ala.	19
10	Dade Co., Fla.	9
		300

¹Special Assignment - Garbage grinder installations.

Distribution by Tank Types

Efforts were made to cover a variety of types of tanks, although freedom of selection in the field was somewhat limited due to the time required to make contacts and investigate installations at widely separated points in an area. The distribution of inspections by tank types is shown in Table 55.

TABLE 55.--Distribution of Total Inspections by Tank Types

Tank Type	Concrete	Tile	Steel	Brick	Concrete Block	Stone	Total
Single vertical cylinder	1	--	61	6	--	1	70
Double vertical cylinder	7	6	--	2	--	--	15
Triple vertical cylinder	4	--	--	--	--	--	4
2 Compartment single vertical cylinder	4	--	1	--	--	--	5
3 Compartment single vertical cylinder	1	--	--	--	--	--	1
Total	17	6	62	8	1	1	95

TABLE 55.--Distribution of Total Inspections by Tank Types--Cont.

Tank Type	Concrete	Tile	Steel	Brick	Concrete Block	Stone	Total
Oval 2 compartment	4	--	--	--	--	--	4
Single horizontal cylinder	1	1	--	--	--	--	2
3 compartment horizontal cylinder	--	3	--	--	--	--	3
Total	1	4	--	--	--	--	5
Single compartment rectangular	99	--	--	16	5	--	120
Double compartment rectangular	32	--	--	10	--	1	43
Triple compartment rectangular	11	--	--	20	1	--	32
Quadruple compartment rectangular	--	--	--	--	--	1	1
Total	142	--	--	46	6	2	196
Grand Totals	164	10	62	54	7	3	300

Inspection Form

Each inspection was made on the basis of a standard inspection form, a copy of which, together with explanation of form items appears in Appendix D. There is also included in the the Appendix a sample inspection report consisting of the executed inspection form, layout and sketches.

Scope of This Report

Eventually an examination of most of the items covered in the inspections will be presented. At the present time an examination of the scum and sludge accumulation data has been made and is presented herein. Field measurements on sludge and scum accumulations are particularly important because such data, together with data on time and contributing persons, cannot be obtained by any other means in a short time. It is useful not only in connection with design storage and cleaning frequency considerations, but may also be useful as an index of efficiency of solids removal.

In order to have as complete a record of the characteristics of each household as practicable in this type of survey, for use in interpreting the various disposal system circumstances found, information was obtained on the number of persons and bedrooms, the metered water usage and the types of units discharging to the septic tank system. While these may not be sufficient numerically to serve as a basis for generalization, they are of importance to the understanding of the particular group of installations examined here, and are presented in summary form in the following paragraphs.

Number of Persons, Bedrooms

The distribution of inspections according to the number of bedrooms and number of resident persons per dwelling is presented in Table 56.

TABLE 56.--*Distribution of Inspections by Resident Persons, Bedrooms*

Number of Bedrooms	Resident Persons									Total
	1	2	3	4	5	6	7	8	9	
1	1	9 ¹	1	-	-	-	-	-	-	11
2	2	32	64	51	17	2	1	1	-	170
3	1	2	13	42	14	9	2	-	-	83
4	-	1	2	5	6	5	1	-	1	21
5	-	-	1	-	1	2	3	1	-	8
6	-	-	-	1	-	1	-	-	-	3
	4	44	81	99	38	19	8	2	1	296

¹Households to right of line have more than two persons per bedroom.

From these data it is determined that for this group, the average number of bedrooms per dwelling was 2.49, the average number of persons per dwelling, 3.83, and the average number of persons per bedroom, 1.5. Most of the dwellings involved had less than two persons per bedroom, the distribution being as shown in Table 57.

TABLE 57.--*Summary - Persons per Bedroom*

Homes		Per Cent
25	more than 2 persons/bedroom	8.5
69	2 persons/bedroom	23.3
202	less than 2 persons/bedroom	68.2
296		100

Water Use

In selecting survey areas efforts were made to locate areas which, in addition to other advantages for survey purposes, had metered water supplies. Inspections in areas having community water supplies were desired by the Housing Agency as being representative of the usual circumstance in F.H.A. involved installations. The metered records were of value as a guide to the amount of sewage being discharged. The summary is presented in Table 58. It is interesting to note that for the 170 installations for which summer and winter figures were available, the summer usage, averaging 48.7 gallons per capita, closely approaches the 50 gallons per capita sewage flow figure used often in the past for household septic tank design considerations. Considering lawn watering usage during the summer the sewage flow figure would probably fall somewhere between the 49 gallon summer and 39 gallon winter per capita water consumption figures for this group. It appears therefore that the customary 50 gallons per capita average design flow would apply rather closely to this small group of dwellings. Attention is called however to the wide range of 226 gallons maximum, and 8 gallons minimum, for individual households in this group. It is of interest to note that average water consumption per person decreases with increasing size of family.

TABLE 58.--Summary Metered Water Use

Metered Water Use - Gal./Capita/Day

Persons Resident	No. of Reports	Summer				Winter			
		Mean	Median	Max.	Min.	Mean	Median	Max.	Min.
1	1	58				50			
2	26	78	62	226	16	53	48	100	8
3	45	50	44	149	14	41	36	106	12
4	58	41	39	104	8	34	30	85	12
5	24	42	41	170	15	35	34	150	13
6	9	36	30	109	20	30	25	77	15
7	5	37	35	69	12	28	25	55	10
8	1	32				22			
9	1	23				23			
	170	48.7(wtd)		226	8	38.5(wtd)		150	8

Waste Disposal Distribution

A variety of waste disposal arrangements were encountered in the field. While it was the intention to examine installations for which all waste, exclusive of roof and other drainage, were discharged to the septic tank, it was found that the field teams would have to spend most of their time screening the field for such installations and the survey was not therefore limited to such installations. The distribution of installations arranged according to waste disposal circumstances and survey area is presented in Table 59 together with an indication of the number of cases in which laundry was done at home and those in which it was not.

TABLE 59.--Waste Disposal Distribution at Field Installations

Wastes to Septic Tank	Distribution by Areas										Total	
	1	2	3	4	5	6	7	8	9	10	No.	Per Cent
Bathroom, kitchen, laundry	5	15	12	17	17	2	15	0	3	1	87	29.9
Bathroom, kitchen	9	42	7	9	12	4	10	0	6	8	107	36.8
Bathroom, laundry	0	2	4	0	0	0	0	0	1	0	7	2.4
Bathroom only	2	27	20	8	10	4	9	0	9	0	89	30.6
Water closet only	0	0	1	0	0	0	0	0	0	0	1	0.3
Total	16	86	44	34	39	10	34	0 ¹	19	9	291	100.0
Laundry not done at home	11	13	4	12	4	4	7	0	12	4	71	24.8
Laundry done at home	5	71	40	20	35	5	27	0	7	5	215	75.2

¹No inspections completed this area - garbage grinder assignment.

Laundry at home	=	215	=	100.0%
Laundry through tank	=	94	=	43.7%
Laundry not through tank	=	121	=	56.3%

Condition of Structural Materials

Field engineers were instructed to include observations of the condition of septic tank structural materials with respect to deterioration. Data on 244 concrete, concrete block, tile, brick and steel tanks are available in this connection.

It was evident from these observations that corrosion was most severe at and above the water line. In general, pre-cast concrete, tile and brick stood up well for periods of 20 years or more; poured-in-place concrete, for at least 10 years (no data on older tanks); steel tanks averaged a 7 year useful life, running to 12 years in the group of tanks inspected.

The examination of the data for the various structural materials follows:

Concrete

Of 150 concrete septic tanks, ranging in age from one-half to 39 years, 136 (91 per cent) were judged to be in good or excellent condition so far as the concrete was concerned. The distribution by age and condition is shown in Table 60.

TABLE 60.--Age vs. Condition Concrete - 150 Septic Tanks

Age Group Years	Number of Tanks		
	Total	Excellent, Good	Fair, Poor
1/2 - 5	45	42	3
6 - 10	77	68	9
11 - 20	17	16	1
21 - 39	11	10	1
	150	136	14

Arrangement of data by wall thickness for a group of 87 concrete septic tanks, ranging in age from one-half to 39 years, and for which 76 (88 per cent) were judged to have concrete in good or excellent condition, resulted in a poor distribution, with practically all of the tanks over 10 years old falling in the thin wall group. Thus, while the data indicate that the thicker wall (presumably poured-in-place) concrete stood up well for at least 10 years, behavior beyond that point is not known. Because of the availability of data on older tanks in the thin wall (presumably pre-cast) group it can be said that such concrete appears to stand up well for periods of at least 20 years. There were 7 thin walled tanks with concrete in good condition at 20 to 39 years. The distribution by wall thickness, age and condition is presented in Table 61.

TABLE 61.--Wall Thickness vs. Age vs. Condition Concrete -
87 Septic Tanks

Wall Thickness		Number of Tanks by Age Groups									
		Excellent, Good					Fair, Poor				
Inches	Total	Total	1/2 to 5	6 to 10	11 to 20	21 to 39	Total	1/2 to 5	6 to 10	11 to 20	21 to 39
1 1/2 to 3 1/2	31	27	8	7	8	4	4	1	2	0	1
4 to 5 1/2	35	31	14	17	0	0	4	1	2	1	0
6 to 12	21	18	13	4	1	0	3	2	1	0	0
Total	87	76	35	28	9	4	11	4	5	1	1

Concrete Block

Six tanks were judged to be in good condition at one-half, 1, 1, 2, 2 and 5 years respectively. None were judged in poor condition. Water was found in the wall of one tank.

Vitrified Tile

Six tanks were found in good condition at 3, 4, 8, 15, 20 and 20 years respectively. A seventh tank was judged fair or poor at 8 years.

Brick

Forty-two tanks with brick in good condition at 1 to 30 years were reported. Five others were judged fair or poor at 6, 7, 11, 17 and 40 years respectively.

Wood

No wooden tanks were encountered in the areas inspected. However, some data are available on wood baffles. In six tanks the wood baffles were found to be sound at three-quarters, 1, 1, 2, 3 and 7 years. Rotted wood forms were found in a tank 17 years old.

Steel

The structural condition of steel septic tanks was classified from available field reports. All reports of field inspections of steel tanks were surveyed for use in compiling this summary. However, no definite instructions had been issued to field engineers for judging the structural condition of steel tanks, hence not all reports of steel tank inspections were usable when applying these criteria finally selected. Written statements concerning the tanks, as well as photographs made at the time of inspection were used in preparing this summary, and reports on 40 steel tanks were used. The tanks were grouped into four general classifications according to the following criteria. These criteria were adopted from those applied by a steel tank manufacturer in judging the effective life of steel tanks.

Class I Good - practically no break in coating applied to the tank at time of manufacture.

Class II Fair - coating starting to break through - bare metal in spots - no holes.

Class III Poor - holes in cover or baffles - rusted.

Class IV Gone - baffles or cover almost rusted away - holes in baffles which allow passage of scum to disposal field.

TABLE 62. -- *Corrosion of Steel septic Tanks*

Class	No. Obs.	Years in Service			
		Mean	Median	Max.	Min.
I	3	2.5	1	6	0.4
II	9	6	6	12	3
III	14	7	6	11	5
IV	14	9.5	8	17	5

From an analysis of the data presented, it appears that the average useful life of steel tanks is approximately 7 years. It is probable that a longer effective life might be realized, since the criteria of Class III do not infer that any large holes exist, however,

the ultimate failure of the tank to provide for normal functions apparently occurs within a short time as evidenced by the mean years of service in Class IV.

In applying the results of this analysis, it must be borne in mind that the effective life of a tank is apparently dependent to a large extent on the effectiveness of the coating applied to the steel. Any cracks or breaks in the coating will materially affect the life of the tank. In judging the probable effective life of any particular tank, consideration should be given to the thickness and composition of the inside coating, and the thoroughness with which it has been applied.

Distribution of Tanks by Years of Service

It was considered important to cover a wide range of years of service, preferably on tanks installed without subsequent servicing, and the bulk of the tanks examined fall in this category. The remainder were tanks which had been cleaned, in which case the years of service considered were those extending from the date of last cleaning.

The distribution by years of service, as interpreted above, is presented in Table 63 for a group of 205 tanks screened out for detailed consideration. It will be noted that it became difficult to find tanks in the upper ranges of years of service.

TABLE 63.--*Distribution of Tanks by Years of Service*

Years of Service ¹	No. of Insp.	Years of Service	No. of Insp.
0.5	4	8	23
0.75	4	9	19
1.0	13	10	4
1.5	2	11	6
2.0	13	12	5
3.0	24	13	4
4	14	16	1
5	14	20	3
6	30	21	1
7	18	32	2
		39	1
Total			205

¹Where tanks had been cleaned, years of service were counted from the date of last cleaning (22 per cent had been cleaned, 78 per cent had never been cleaned).

Measurement of Scum and Sludge

Each field team was equipped with a set of tools and various measuring devices designed in connection with the inspection work. Included in each kit was a scum thickness measuring device patterned after that used in the Illinois study, consisting of a hinged plate, on a tube handle, which was slipped through the scum layer in vertical position, rotated to a horizontal position, and pulled up against the bottom of the scum for measurement. The sludge level indicating device, developed by personnel on this Project, was a jointed copper tube with a water tight window at the bottom, below which was fixed a flashlight bulb. The inspector observed the light bulb through the tube as the tube was lowered into the tank. The light blanked out at the sludge level recorded as the top of sludge. The results were reproducible by different operators in the neighborhood of one-eighth inch. This device worked excellently and was preferred over previously reported methods of lowering and withdrawing a sample bottle at various depths, until solids content indicated the sludge level.

depth had been reached, at risk of disturbance of tank contents. Sketches of both of these devices appear in Appendix D.

Examination of Septic Tank Sludge and Scum Accumulation Data

Of the 300 installations inspected in the field, 205 were screened out for detailed examination as being able to satisfy all of the following criteria:

1. A single household is served.
2. A reasonably accurate history was obtained.
3. The tank was not full of scum and sludge.
4. The outlet device was intact.

There is included in this group of 205 tanks a variety of shapes, sizes, water depths, circumstances of compartmentation and internal detail, and, as indicated earlier, the waste hook-up circumstances range from bathroom only, to the entire household waste, exclusive of roof runoff and other drainage.

It is evident that the 205 cases available for examination are far short on numbers to enable breakdown on the basis of each variable individually for comparison. However, it is felt that some trends derived from a broader group consideration may be of value, provided the limitations of such examinations are kept in mind. As mentioned previously, scum and sludge data from the field are useful in indicating trends in the per capita rate of accumulation, which is of importance to consideration of design capacity and cleaning interval. The solids accumulation in a tank after operation for a particular time and loading may also be a guide to the performance of that tank in the removal of solids. Comparison of tanks on this basis involves the assumption that digestion rates and sludge densities are about the same for various septic tanks in the range of size involved in the household system. This appears to be a reasonable assumption although its validity by test has not been established. Such examination of the experimental septic tank results as has been made thus far is inconclusive on this point.

An examination of the 205 tanks was first made on the basis of sludge and scum found in the tanks, as related to number of contributing resident persons and years of service during which the accumulation took place. The accumulations were reduced to a hypothetical annual rate of accumulation per person by dividing the total accumulation by the years of service, and, again, by the average number of persons connected, obtaining the expression, average cubic feet per capita per year. This figure, when multiplied by the number of persons, and number of years of operation, equals the total observed accumulation. The mean and median values of such rates for the 205 tanks, grouped by years of operation are presented in Table 64. The mean values are spotted on Plate 18 upon which the resulting trend curves are also plotted.

Average Trends 205 Household Septic Tanks

Before discussing the trends indicated on Plate 18 it should be kept in mind that these represent trends of average values of a group of tanks differing individually in size, type and internal detail and are useful principally in tracing the general course of sludge and scum accumulations as against time, and as a rough yardstick for comparison of several design characteristics on the basis of solids retention.

It may be noted from the trend curve of scum and sludge accumulation indicated on Plate 18 that the average per capita annual rate of accumulation may be upwards of 3.4 cubic feet during the first year of operation, falling off, presumably because of digestion and compaction, to 1.34 cubic feet at about the 6 or 7 year point, beyond which it appears to continue at 1.34 cubic feet. In other words, the sludge plus scum appears to accumulate, volumetrically, at a much higher rate per person in the earlier years of tank life than it does after 6 years of operation.

TABLE 64.--Mean and Median Scum and Sludge Accumulation Rates

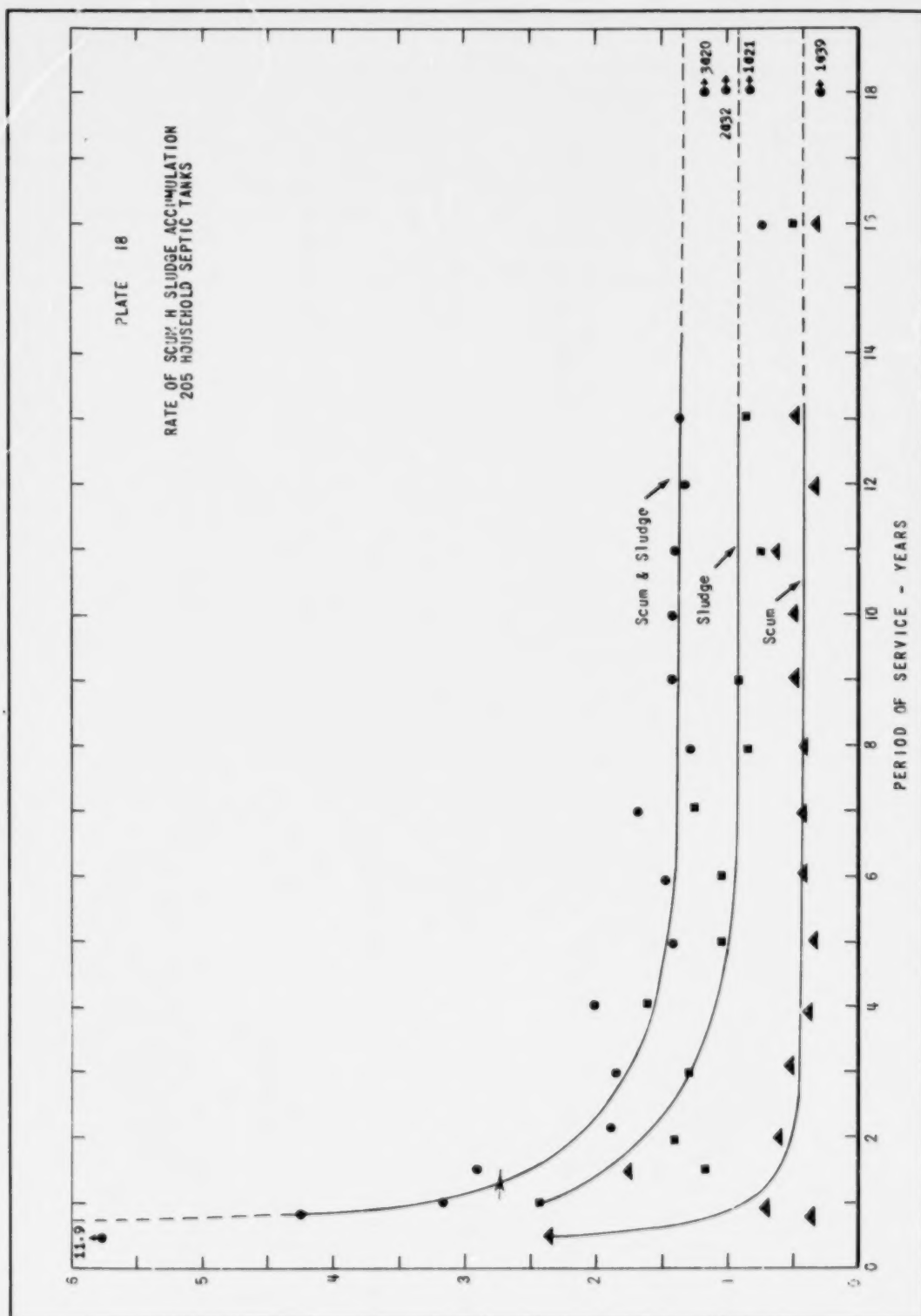
Determined from Measurements 205 Household Septic Tanks
Volume in cu. ft./Capita/Year

Years of Service	No. of Reports	Mean Scum	Mean Sludge	Mean Sc & Sl	Median Scum	Median Sludge	Median Total Scum & Sludge
1/2	4	2.32	9.55	11.87	2.62	8.43	11.98
3/4	4	0.38	4.19	4.27	0.00	4.33	4.60
1	13	0.69	2.44	3.13	0.27	2.17	3.02
1-1/2	2	1.75	1.14	2.89	1.75	1.14	2.89
2	13	0.54	1.36	1.90	0.38	1.25	2.06
3	24	0.54	1.28	1.82	0.41	1.04	1.60
4	14	0.42	1.59	2.01	0.37	1.28	1.94
5	14	0.34	1.06	1.40	0.26	1.04	1.31
6	30	0.42	1.04	1.46	0.41	0.90	1.39
7	18	0.40	1.24	1.64	0.42	1.10	1.58
8	23	0.42	0.85	1.27	0.33	0.78	1.09
9	19	0.48	0.90	1.38	0.41	0.79	1.28
10	4	0.44	0.95	1.39	0.40	1.03	1.38
11	6	0.68	0.71	1.39	0.73	0.70	1.39
12	5	0.34	0.97	1.31	0.26	0.55	1.18
13	4	0.48	0.89	1.37	0.53	0.80	1.42
16	1	0.26	0.46	0.72	0.26	0.46	0.72
20	3	0.24	0.94	1.18	0.25	1.10	1.35
21	1	0.02	0.82	0.84	0.02	0.82	0.84
32	2	0.34	0.63	0.97	0.34	0.63	0.97
39	1	0.05	0.21	0.26	0.05	0.21	0.26

TABLE 65.--Total Per Capita Sludge and Scum Accumulation

(based on average trends of accumulations in 205 tanks as indicated on Plate 18)

Cu. ft./cap./year				Total cu. ft./cap.		
No. Years	Scum	Sludge	Scum & Sludge	Scum	Sludge	Scum & Sludge
1	0.83	2.45	3.28	0.83	2.45	3.28
2	0.47	1.63	2.10	0.94	3.26	4.20
3	0.43	1.28	1.71	1.29	3.84	5.13
4	0.43	1.09	1.52	1.72	4.36	6.08
5	0.43	1.00	1.43	2.15	5.00	7.15
6	0.43	0.95	1.38	2.58	5.70	8.28
7	0.43	0.92	1.35	3.01	6.44	9.45
8	0.43	0.92	1.35	3.44	7.36	10.80
9	0.43	0.92	1.35	3.87	8.28	12.15
10	0.43	0.92	1.35	4.30	9.20	13.50
11	0.43	0.92	1.35	4.73	10.12	14.85
12	0.42	0.92	1.34	5.04	11.04	16.08
13	0.42	0.92	1.34	5.46	11.96	17.42
14	0.42	0.92	1.34	5.88	12.88	18.76
15	0.42	0.92	1.34	6.30	13.80	20.10
16	0.42	0.92	1.34	6.72	14.72	21.44
17	0.42	0.92	1.34	7.14	15.64	22.78
18	0.42	0.92	1.34	7.56	16.56	24.12
19	0.42	0.92	1.34	7.98	17.48	25.46
20	0.42	0.92	1.34	8.40	18.40	26.80



It is seen also that the sludge exerts the greater influence on the change in the overall rate, becoming constant at 0.92 cubic feet per capita annually at about the 7 year point, whereas the scum drops rapidly from a rate of 0.8 or more cubic feet during the first year down to 0.42 cubic feet per capita annually at the 3 year point beyond which the rate of accumulation appears constant at 0.42 cubic feet per capita per year. The ratios of scum and sludge accumulation rates to the total are 31 and 69 per cent respectively at the 7 year mark and beyond.

The change in average rate of accumulation of solids as the period of service increases is of much interest in considering provision for scum and sludge capacity in household tank design. There is shown in this connection, in Table 65, the computed total accumulation of scum and sludge at the end of various periods of operation. These are on a per capita basis and on Plate 19, curves of these values. It is of interest to note that the total accumulation, per person, at the end of one year is about 3.25 cubic feet, that twice this amount does not accumulate until 4.5 years operation, three times-7 years, four times-almost 9.5 years, five times-12 years, and so on. It would appear from this that an average tank, providing 3.25 cubic feet per capita of scum and sludge storage capacity at its cleaning point, would require cleaning at one year intervals, whereas provision for double the storage space would reduce the frequency to once in 4.5 years, and, for 5 times the one year amount, to 12 years.

Scum Buoyancy

Design of scum retention devices involves some knowledge of scum buoyancy. In order to supply some factual data on this item the field engineers were asked to include measurements of the scum as related to the water level. The scum measurements for 150 tanks obtained in this connection were classified by scum thickness and group averages obtained on the height of scum above the water line. The straight line trend obtained is shown on Plate 20 and indicates that for scum layers up to 28 inches thick, about 27 per cent of the total thickness will be exposed above the water line, and 73 per cent, below it.

Effect of Type of Waste on Scum and Sludge Accumulation

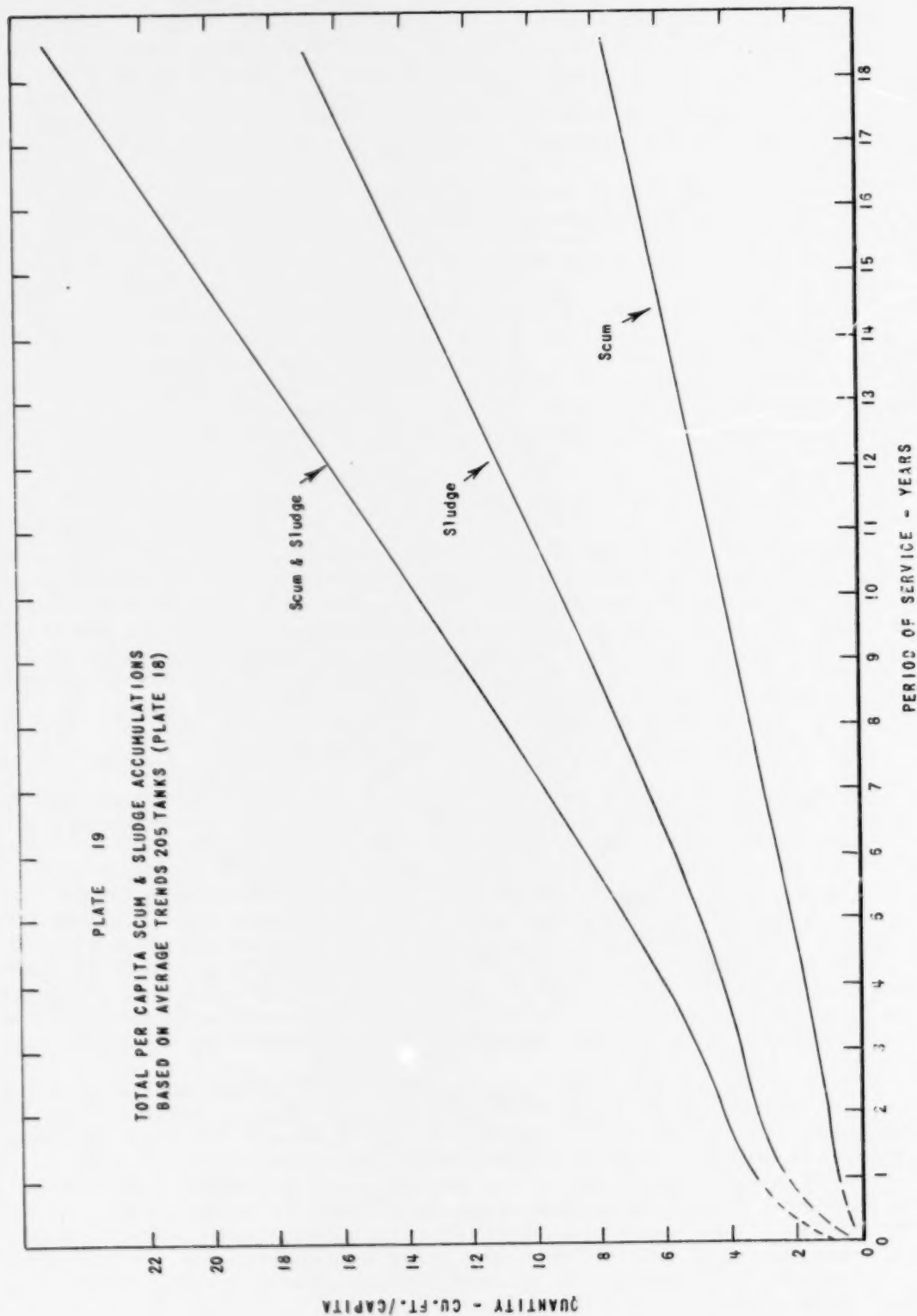
The separation of wastes at a number of the household systems inspected provided the opportunity to compare the solids accumulating from the discharge of bathroom wastes (bath-tub, lavatory and water closet) only, to the septic tank, with those resulting from the discharge of all household wastes (bathroom plus kitchen and laundry) to the tank. Data for 62 installations receiving the bathroom waste only, and for 80 installations wherein all wastes were discharged to the septic tank, were utilized for the comparison. In no case were the kitchen and laundry wastes passed through a grease trap before entering the septic tank.

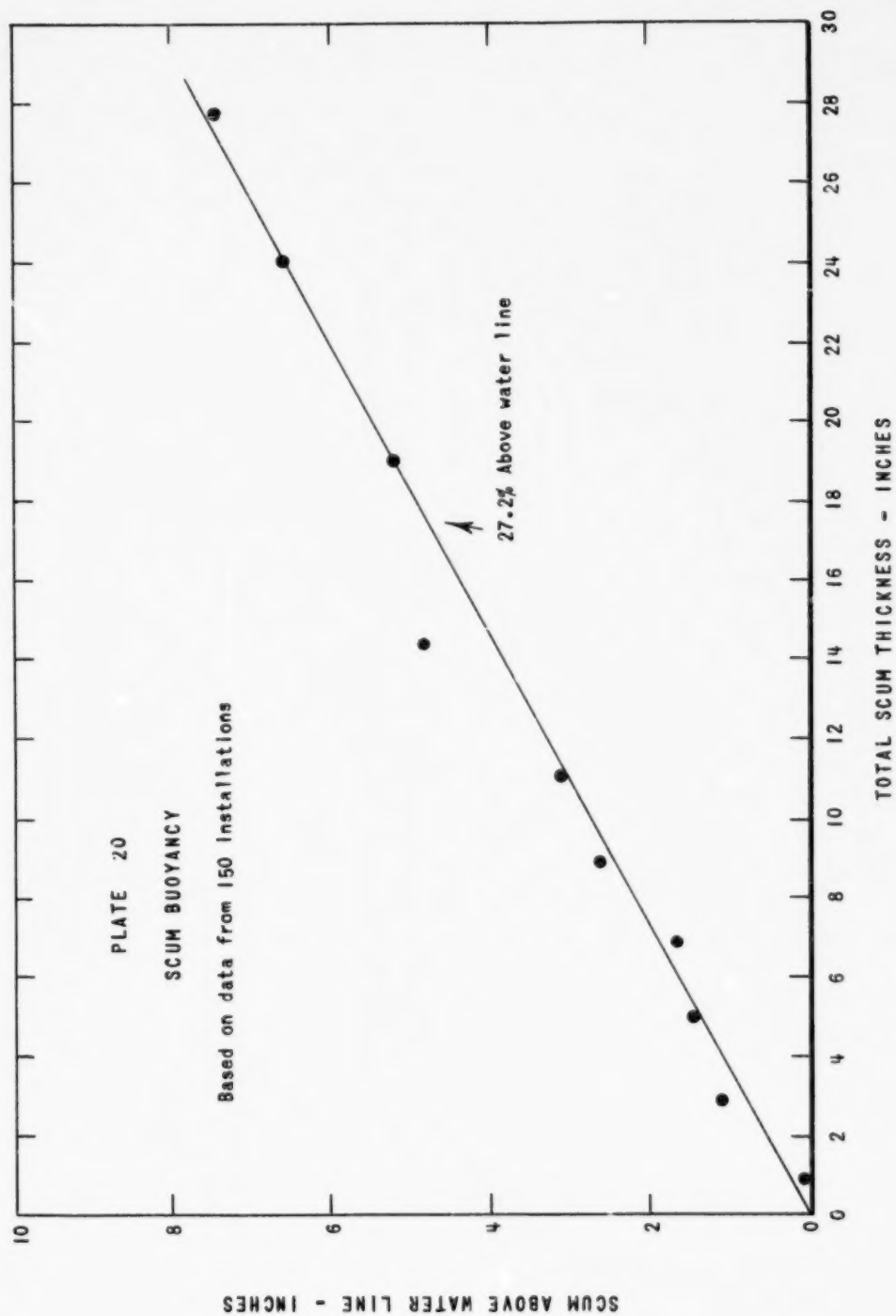
As in the previous examination the individual installations were classified by years of service and the average cubic feet per capita per year sludge and scum accumulations averaged for the classified groups. The resulting values and trend curves are plotted on Plate 21, together with the average trend curve developed previously for the overall group of 205 tanks.

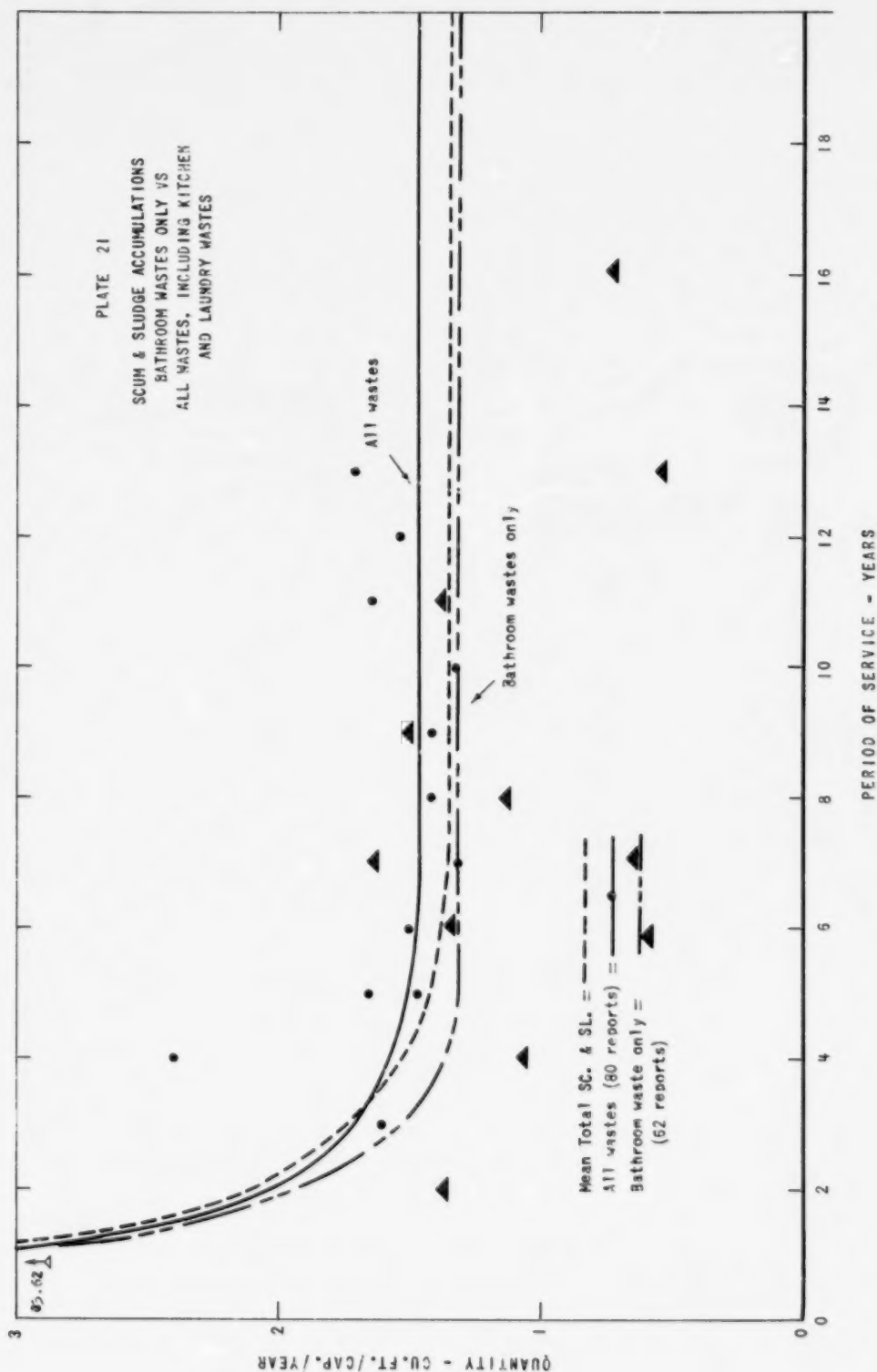
It is seen from the trend curves that the average annual per capita accumulation for the tanks receiving all wastes is about 1.46 beyond the 6 year point, as against 1.31 for the bathroom wastes, a difference of 0.15 cubic feet per capita annually. It might appear from this that the inclusion of kitchen and laundry solids, including fats and soaps, adds but 11 per cent to the amount of solids accumulating from bathroom wastes alone. There is an element of weakness in this comparison, because of possible lowering of efficiency of sedimentation in the group of tanks receiving the higher flows. It is worth noting in this connection, however, that the average rate of accumulation in the 80 tanks receiving the total wastes lies slightly above that of the entire group of 205 tanks previously examined, indicating at least average efficiency in solids retention.

PLATE 19

TOTAL PER CAPITA SCUM & SLUDGE ACCUMULATIONS
BASED ON AVERAGE TRENDS 205 TANKS (PLATE 18)







Effect of Capacity

It was indicated previously that, for the average tank in the group of 205 examined on the basis of per capita solids accumulation and length of service, an increase in solids storage space appeared to extend the cleaning interval considerably. In this section an examination of per capita solids accumulation and per capita capacity is made, to learn whether increased capacities result in increased solids retention.

The 205 tanks were classified according to years of service and per capita liquid capacity in one or another of a series of 6 capacity ranges as follows: less than 75 g.p.c., 75 to 125, 125 to 175, 175 to 225, 225 to 275, and, over 275 g.p.c. The average annual per capita sludge accumulation for each individual installation in the several capacity groups was then plotted for comparison with the average trend line of solids accumulations for the total group of 205 tanks, as shown in Plates 22, 23 and 24. It will be noted that the bulk of the small capacity tanks, that is, those in the less-than 75 g.p.c., and the 75 to 125 g.p.c. groups, fall below the mean curve of per capita solids accumulation; those in the 125 to 175 g.p.c. range straddle the average trend; while the bulk of those in the larger capacity groups, 175 to 225, 225 to 275, and above 275 g.p.c., are above the mean.

The indication here is that tanks with capacities of less than 125 to 175 gallons per capita retain less solids per capita than the average of the group, while tanks of greater capacity than those in the 125 to 175 gallons per capita group retain more solids per capita than the average, and are therefore more efficient so far as solids removal is concerned.

The trend curves for the average accumulations in the capacity groups are plotted on Plate 25, which probably shows more clearly the differences in solids accumulation rates for the several capacity groups. Note that the per capita accumulation trends in the less-than-75 g.p.c. and 75 to 125 g.p.c. groups were below average, while those in the 125-175 g.p.c. group and in the larger capacity groups were more effective in the removal of solids.

On Plate 26 is plotted the solids accumulation rates against capacity for 100 installations in service for six years or longer. The six year minimum was selected because accumulation trends appear to flatten out into a constant rate of accumulation beyond this point, enabling use of the whole field for trend. It appears from the general trend shown here that tanks providing less than 100 g.p.c. capacity tend to accumulate less than 1 cubic foot per capita per year of solids.

The wide variation in individual values evident on Plate 26, indicates the risk involved in attempting to generalize on the basis of one installation, or even a small group of installations in this field.

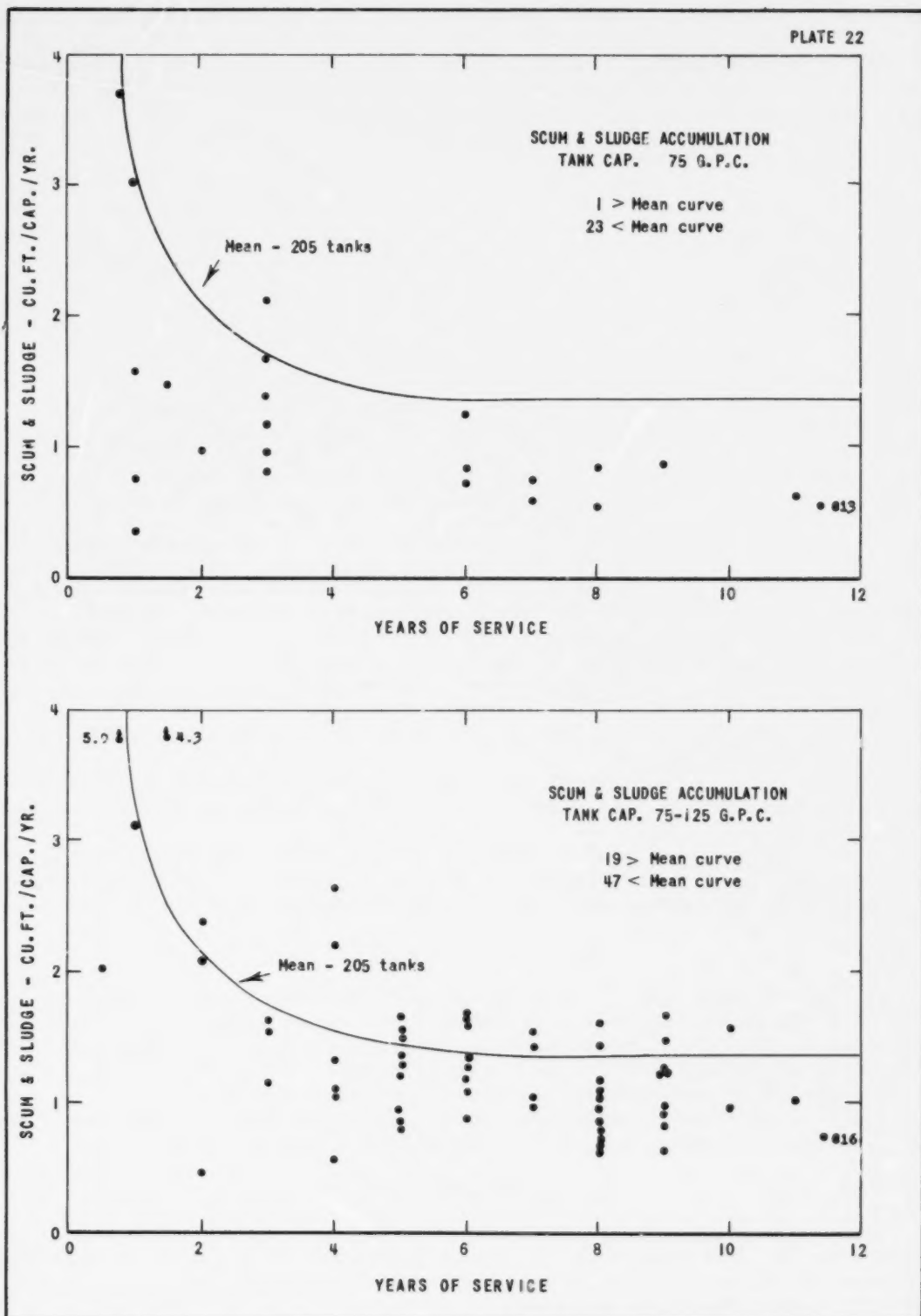
It may be noted also from the trend shown in Plate 26 that the average rate of accumulation of scum and sludge, 1.34 cubic feet per capita annually, indicated beyond the six year point on Plate 18, falls at about 135 gallons per capita capacity.

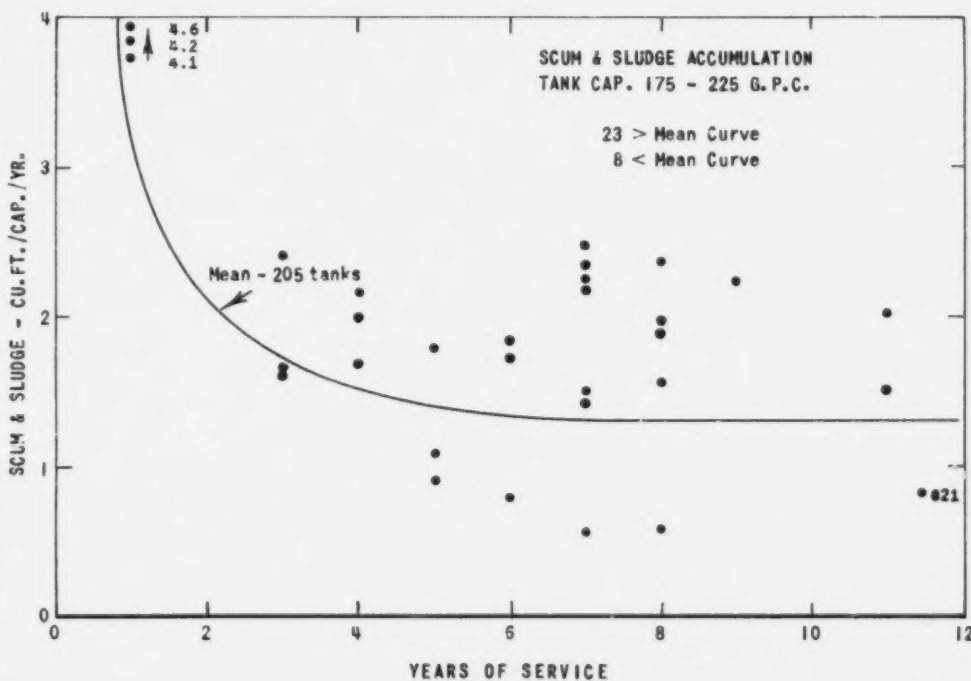
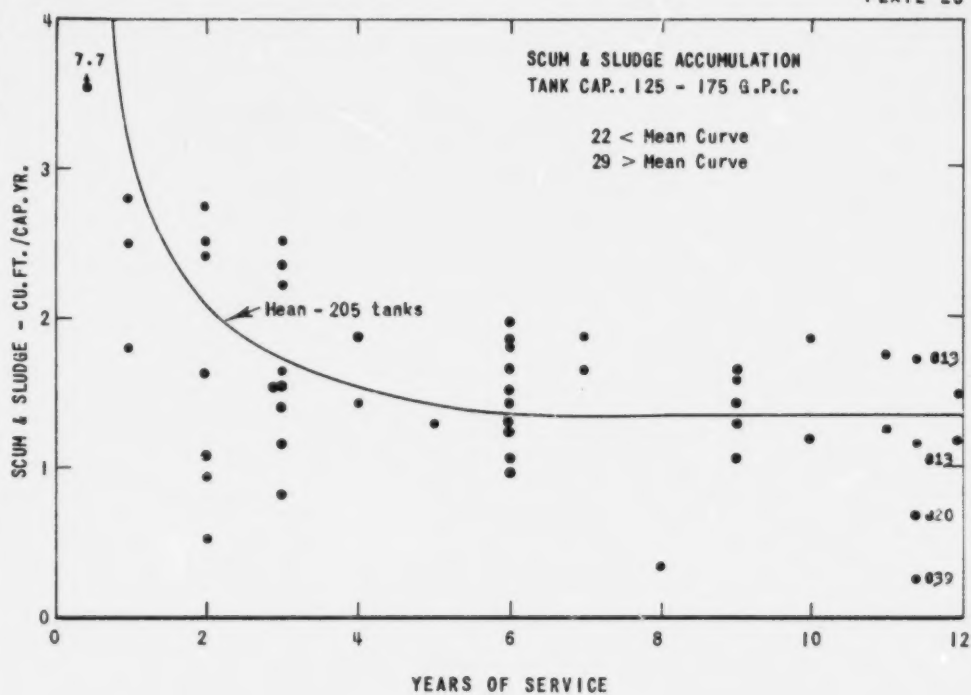
Effect of Liquid Depth

Preliminary examination of field data on depth characteristics has been made. On Plate 27 has been plotted the average per capita solids accumulations for a group of 116 household septic tanks classified by depth. As the graph indicates the trend appears to be an increase in solids removal with increasing depth. However, the influence of capacity has not been eliminated in this preliminary examination and too much weight should not be given to the result at this time. Further study of the data on this point will be made, if the number of installations are sufficient to enable breakdown on this point.

Effect of Surface Area

The results of preliminary examination of surface area against solids removal are shown on Plate 28. Here again while the accumulations appear to increase with increasing surface area the influence of capacity is present and more indicative signs await future opportunity to examine the data in more detail.





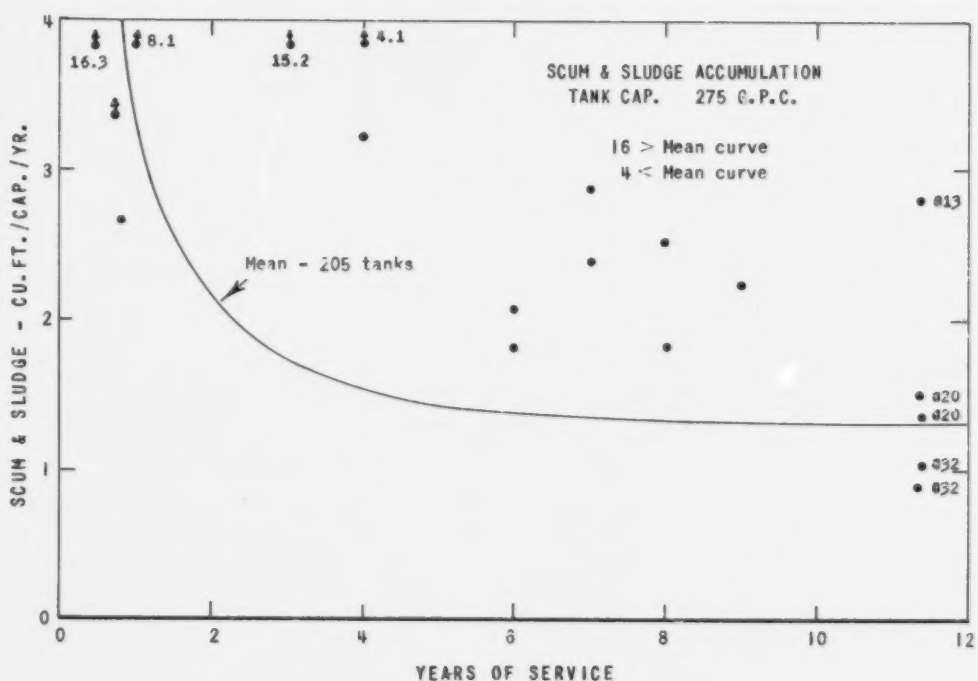
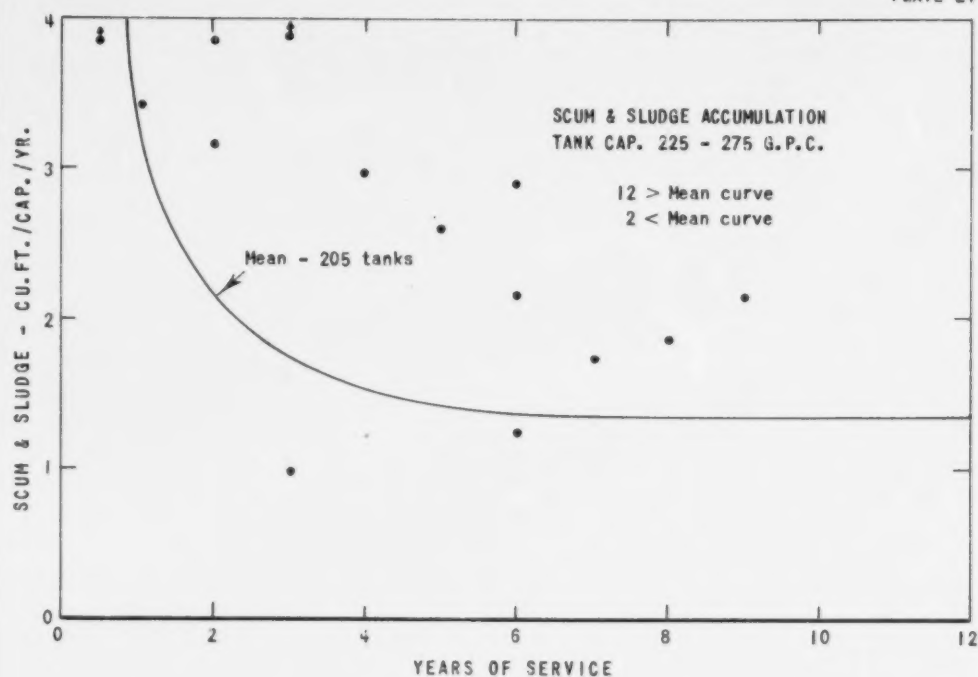
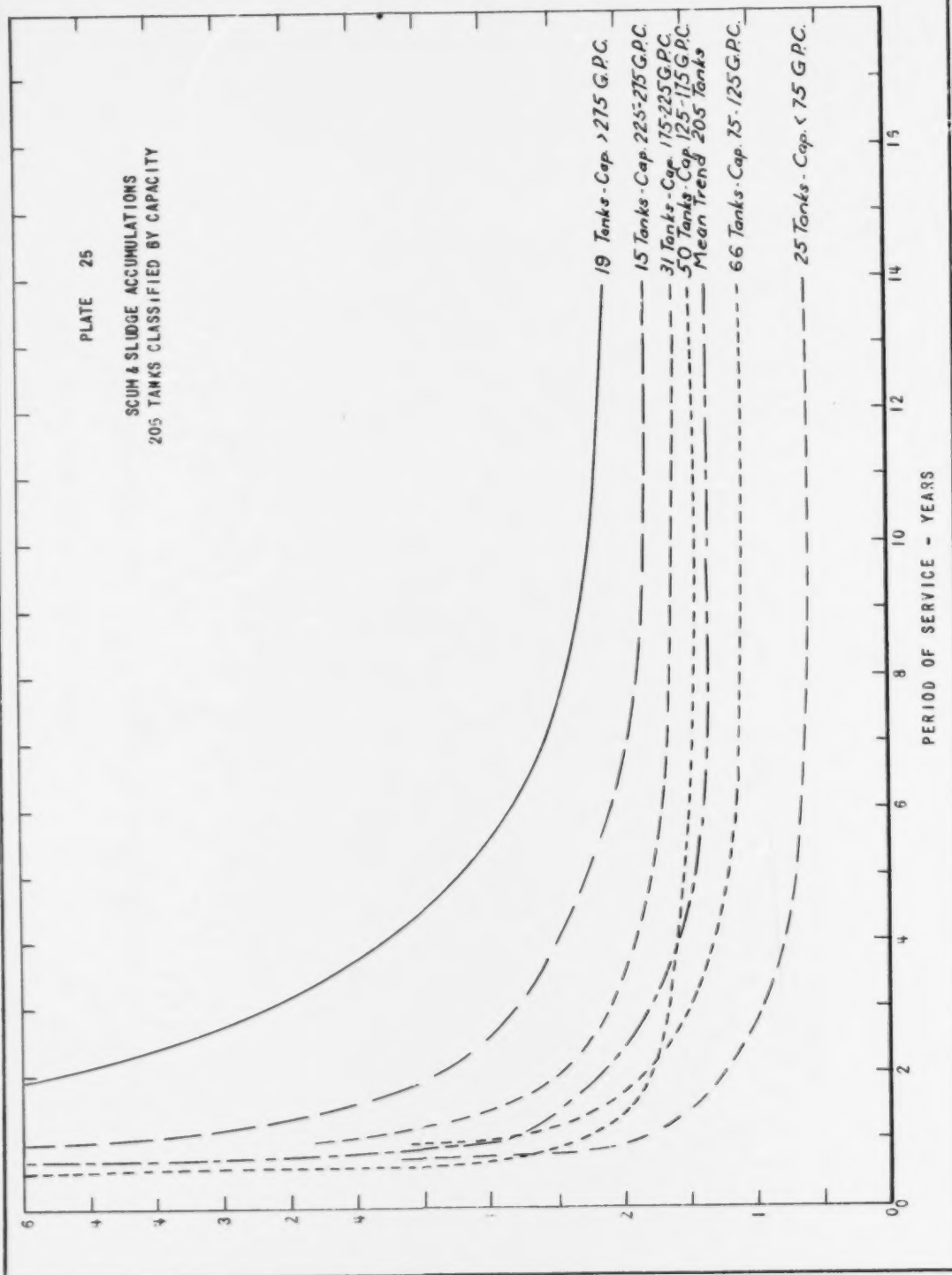
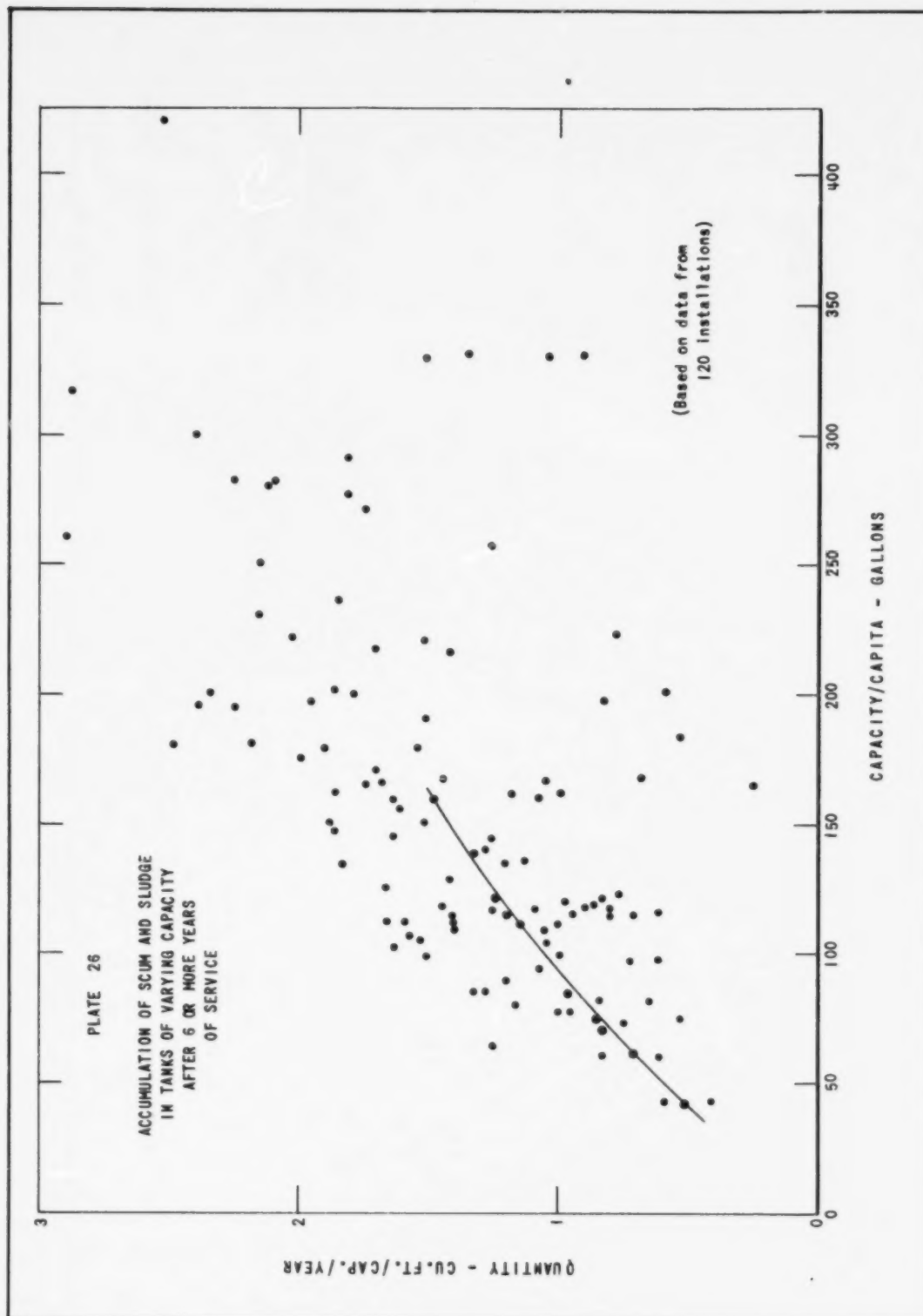
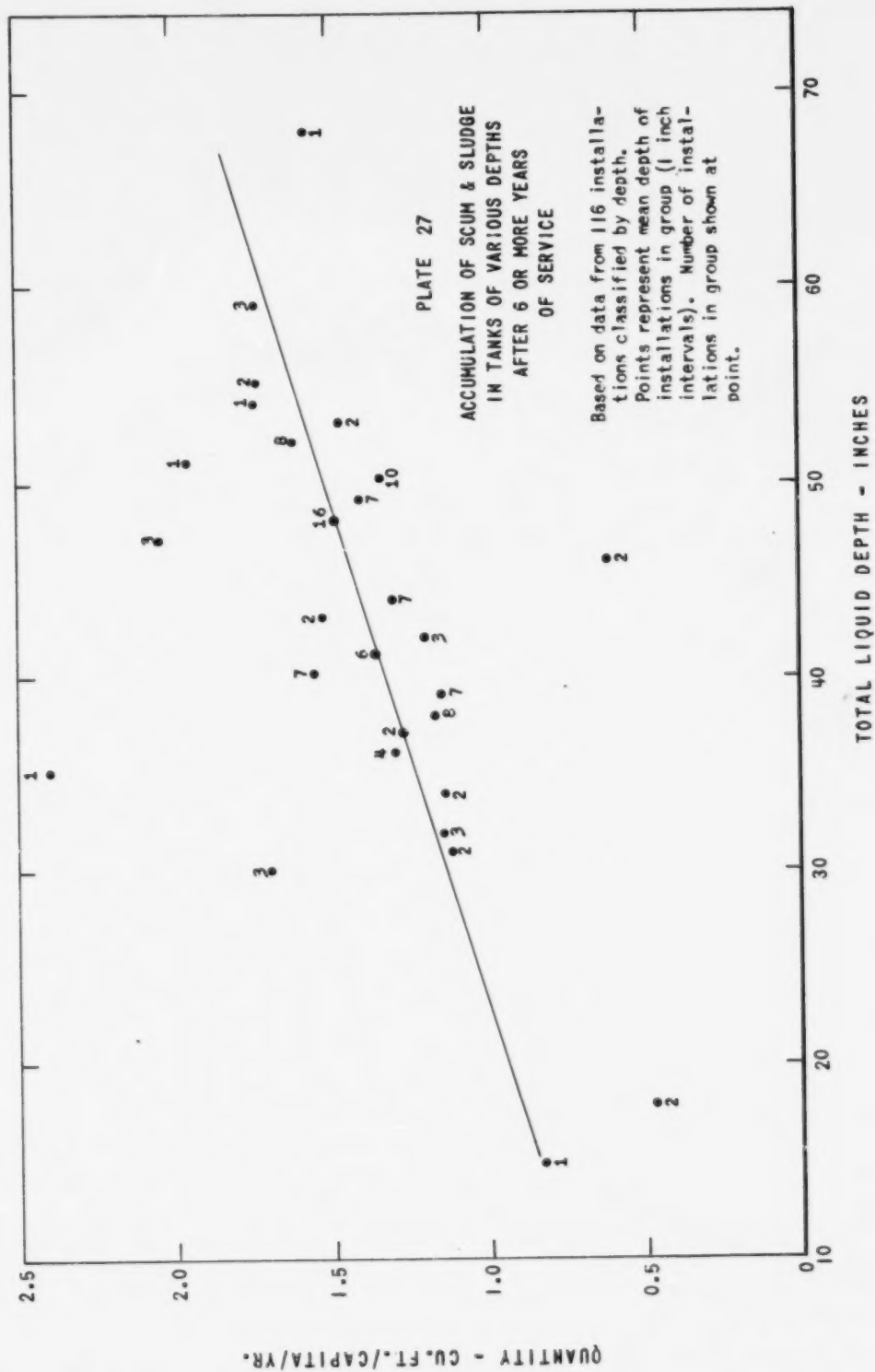


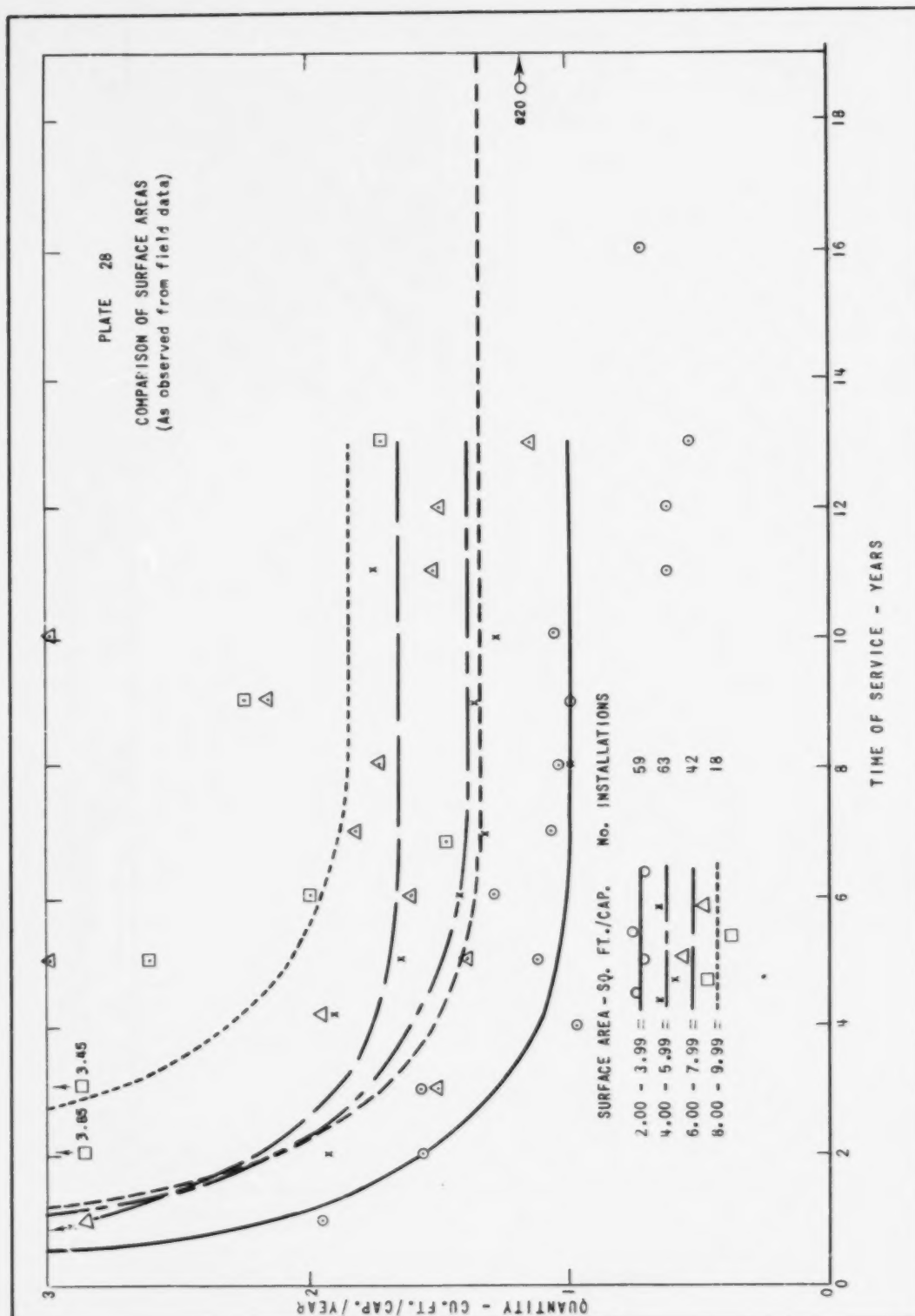
PLATE 25

SCUM & SLUDGE ACCUMULATIONS
205 TANKS CLASSIFIED BY CAPACITY









Summary

1. A total of 300 household septic tank systems were inspected in 9 geographical areas over the country.

2. Statistics on household characteristics indicated that for 296 of these households the number of bedrooms per dwelling was 2.49, and the number of persons per bedroom averaged 1.5. Metered water usage at 170 of the group averaged 49 gallons per capita daily in the summer as against 39 during the winter.

3. Examination of data on the condition of structural materials in 244 concrete, concrete block, vitrified tile, brick and steel septic tanks revealed that corrosion was most severe at and above the water line. In general, pre-cast concrete, tile and brick stood up well for 20 years or more; poured-in-place concrete, for at least 10 years (no data for older tanks); steel tanks averaged a 7 year useful life, running as high as 12 years in individual cases in the group of tanks examined. Wood baffles were found sound in tanks up to 7 years old.

4. For 205 tanks considered, the average sludge and scum accumulation rates for the group tended to be upwards of 3.4 cubic feet per capita per year during the first year, dropping down, presumably because of digestion and compaction, to 1.34 cubic feet per capita per year at the 6 or 7 year mark and continuing on at that rate. On this basis, twice the one year effective sludge and scum storage capacity would appear to extend the interval between cleanings to 4-1/2 years; three times, to 7 years.

5. Measurements of scum layers on 150 tanks indicate that about 27 per cent of the total thickness will lie above the water line.

6. Scum and sludge accumulations in 80 tanks receiving all wastes, average only 0.15 cubic feet per capita annually more (11 per cent) than the average accumulation rates for 62 tanks receiving bathroom wastes only.

7. Capacity appears to be a very important factor in the accumulation of solids. For 205 tanks the average solids accumulation fell in the 125 to 175 gallons per capita group, with less solids accumulation in smaller tanks, more in larger tanks.

8. Solids accumulations appear to increase with depth, although the influence of capacity is not eliminated from this examination.

9. While solids accumulations appear also to increase with tank surface area, capacity again tends to mask the trend.

References

1. Fair and Moore, Heat and Energy Relations in the Digestion of Sewage Solids, VI Mathematical Formulation of the Course of Digestion, Sewage Works Journal, 4:3, 430, (May 1932)

2. Heukelekian, H., Effect of Yeast on the Stabilization of Sewage and Sludge Digestion, Public Works, Sept. 1942, p. 17.

SECTION E

LABORATORY INVESTIGATION OF SLUDGE, YEAST, AS STARTERS

131-4

LABORATORY INVESTIGATION OF SLUDGE, YEAST, AS STARTERS

Sludge as a Starter

In an attempt to answer the question, "How much digested sludge should be added to a digestion (septic) tank for seed purposes?" Graduated quantities of digested sludge ranging from one-half to 20 per cent by volume were added to sewage as seed material.

The sludge used in these experiments was obtained from the Imhoff tank of the Glendale, Ohio, sewage treatment plant, and at the time of use had a volatile solids content of approximately 33 per cent. Graduated amounts of sludge, ranging from 0 to 20 per cent by volume, were added to a series of bottles and filled to the mark with fresh raw sewage, and digestion allowed to progress at room temperature. The quantities of sludge and sewage added are shown in Table 66. Sewage, sludge, and sewage-sludge mixture, characteristics are given in Table 67, together with certain other parameters, including the milliliters of gas produced per gram of volatile solids unaccounted for (presumably lost through digestion). These values indicate the wide variation obtained in applying this criterion to digestion studies. In a discussion of this subject, Fair and Moore (1) write as follows:

"In the study of anaerobic decomposition of sewage matter, or sludge digestion, there have been developed, so far, only two parameters that seem to measure the course of digestion as a mass phenomenon. They are: (1) gas production, and (2) volatile-matter reduction. Of the two, gas production is mostly closely associated with the changes in energy content of the sewage solids. Hence it constitutes on the whole a better parameter of sludge digestion than does volatile-matter reduction."

TABLE 66.--Seed Volume Experiment

Bottle No.	Per cent sludge by volume	Volume in milliliters		Grams sludge volatile matter added	Grams volatile matter added with raw sewage	Ratio sewage to sludge by weight (volatile matter)	Total gas produced cc. (at 190-1/2 hours)	Milliliters gas/gram raw volatile matter added (190-1/2 hours)
		Sludge	Sewage					
G	0	0	9,500	0	3.27	--	100	30.6
A	1/2	47.5	9,452.5	1.36	3.25	1:0.42	560	172.3
B	1	95	9,405	2.72	3.24	1:0.84	55	17.0
C	2	190	9,310	5.44	3.20	1:1.70	1,540	481.3
D	5	475	9,025	13.59	3.10	1:4.38	1,870	603.2
E	10	950	8,550	27.18	2.94	1:9.24	2,135	726.2
F	20	1,900	7,600	54.35	2.61	1:20.82	2,200	842.9

TABLE 67.--Characteristics of Sewage and Sludge

		At Start							
Bottle Number		G	A	B	C	D	E	F	Sludge
Per cent by Volume		0	1/2	1	2	5	10	20	100
Total Solids	p.p.m.	887	1,380	1,583	2,135	4,244	6,837	13,701	85,783
Total Solids Ash	p.p.m.	543	790	932	1,255	2,482	4,080	8,370	57,176
Total Solids Volatile	p.p.m.	344	590	651	880	1,762	2,757	5,331	28,607
pH		7.6	7.6	7.7	7.7	7.7	7.6	7.6	7.6
		At End							
Total Solids	p.p.m.		1,130	1,353	1,673	3,173	5,837	6,912	
Total Solids Ash	p.p.m.		669	892	1,212	2,060	3,626	4,306	
Total Solids Volatile	p.p.m.	338	461	461	461	1,113	2,211	2,606	
Loss in Total Solids Volatile		6	129	190	419	649	546	2,725	
Milliliters of Gas		100	560	55	1,540	1,870	2,135	2,200	
Milliliters of Gas/Gram Volatile Mat. Destroyed		1,754.4	457.0	30.5	386.9	303.3	411.6	85.0	

These authors show a curve describing the observed course of sludge digestion as traced by gas production in which the time in days is plotted along the abscissal scale and the gas production in liters per kilogram raw volatile matter is plotted along the ordinate. Similar curves and data based on the gas production milliliters per gram of raw volatile solids added are presented by Heukelekian in his studies on digestion.

As noted in Table 67 the values obtained on the basis of volatile-solids reduction are extremely variable, due perhaps in part, to the effect of the experimental error in determining volatile solids. This fact is shown in Table 68 in which values are computed from the individual sludge and sewage data are compared with values obtained by test. The data indicate that the differences are greatest when the concentrations of sludge are low and high; intermediate mixtures from 1 to 5 per cent give fairly satisfactory checks. Because of these difficulties the cumulative gas volume produced per gram of volatile solids added in the raw sewage, was utilized as a more satisfactory parameter of the course of digestion.

The gas produced in several periods of time, with various amounts of sludge added to the sewage as a starter, are shown in Table 68A and are traced on Plate 28A. It is seen from Plate 28A that considerable lag developed at the 0, 1/2 and 1 per cent concentrations, as compared with the 2, 5, 10 and 20 per cent concentrations. The curves obtained for the sewage sludge mixture having 2, 5, 10 and 20 per cent sludge are also interesting in that they show increasing rates of gas production with increasing quantities of sludge. Another fact, which may be purely coincidental, is that the differences in the final values plotted for 2, 5, 10 and 20 per cent sludge curves are practically constant; being 122 between curves C and D, 123 between curves D and E, and 117 between curves E and F.

TABLE 68.--Comparison of Computed and Observed Values
Total Volatile Solids in Sewage - Sludge Mixtures

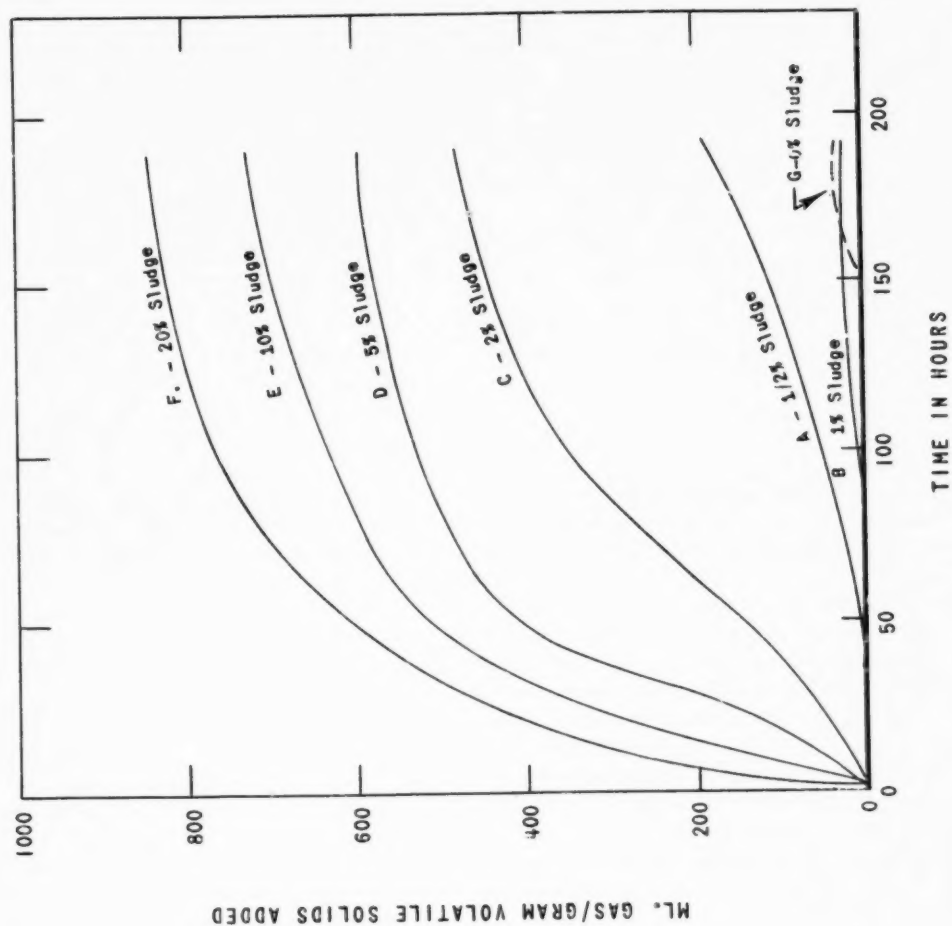
Per cent sludge	Total volatile solids		Computed value test value (3)-(2)	Percent difference based on computed value (4)+(3)x100	Percent Difference based on test value (4)+(2)x100
	Test value p.p.m.	Computed value p.p.m.			
0.5	590	485	-105	-21.6	-17.8
1.0	651	627	-24	-3.8	-3.7
2.0	880	910	+30	+3.3	+3.4
5.0	1,762	1,758	-4	-0.2	-0.2
10.0	2,757	3,170	+413	+13.0	+15.0
20.0	5,331	6,000	+669	+11.1	+12.5

TABLE 68A.--Volume of Gas Produced per Gram of Volatile Solids
Added in Raw Sewage for Various Initial Seed Concentrations

Per cent sludge	Digestion time, hours							
	25	50	75	100	125	150	175	190-1/2
0.5% curve A	0	9.2	22.5	48.3	82.5	119.7	150.8	172.3
1.0% curve B	0	tr	tr	3.1	11.4	17.0	17.0	17.0
2.0% curve C	60.9	157.8	266.6	349.1	408.1	446.9	467.5	481.3
5.0% curve D	181.3	398.4	495.8	531.6	559.4	583.9	591.6	603.2
10.0% curve E	382.2	522.1	589.8	631.3	666.7	699.0	712.9	726.2
20.0% curve F	445.2	597.7	696.2	767.0	796.5	827.6	841.4	842.9
0% curve G	0	0	0	0	0	1.5	24.8	30.6

PLATE 28A

EFFECT OF VARYING SEED
CONCENTRATION IN THE
DIGESTION OF RAW
SEWAGE SOLIDS



If the sludge added was stabilized and would serve purely as a medium for seeding the sewage added, the rate of gas production, it would seem, should have remained practically constant because only the sewage would react. This premise would appear reasonable in view of the fact that the sludge used for seed purposes had a volatile solids content of about 33 percent. As the curves do not appear to reach some constant asymptotic value, the sludge must enter into the phenomenon in some other way. It may be that some particular constituent of the sludge, its identity unknown to us at present, would account for this increase in gas production per gram of volatile solids added with an increase in sludge volume.

Digestion will of course eventually establish itself spontaneously in a tank receiving normal household sewage, provided temperatures are not extreme. The course of such digestion proceeds, however, through a sometimes prolonged odoriferous acid stage before reaching alkaline conditions under which digestion proceeds most effectively, and with least odor nuisance.

In that digestion proceeds slowly at lower temperatures it appears advantageous to seed tanks placed in operation in northern climates, and probably also in any case where the risk of a period of odorous operation would be avoided.

Further work should be done in connection with the study above mentioned, before definite conclusions can be made. It appears that the 1 to 4.38 sewage-sludge volatile solids ratio might serve for seeding purposes. If the household sewage organic solids loading were in the neighborhood of the 145 grams per capita daily loading in an average domestic sewage given by Fair (2), the corresponding volume of seeding sludge such as used in the test reported above, at the 1 to 4.38 ratio would amount to

$$\frac{145 \times 4.38 \times 475}{13.59 \times 3,785} = \text{about 6 gallons per capita.}$$

As indicated above, more work would be needed to fortify this basis.

Yeast as a Starter

The question of adding yeast to septic tanks to "start" them, has been suggested many times. Heukelelian has reported the effect of yeast on sewage stabilization and on anaerobic digestion of a fresh solids-ripe sludge mixture (2). In neither case was yeast found to be beneficial.

In order to observe what effect, if any, yeast has on the anaerobic digestion of fresh sewage alone, bottle experiments were set up and operated as described below. At the conclusion of the first series the experiments were repeated using fresh sewage-ripe sludge mixtures, the results of which are also included.

In the first experiment, varying concentrations of yeast were added to raw sewage and the progress of digestion, as measured by gas production, was compared with that of a control unit containing sewage and digested sludge; the latter serving as a seed material. A stock suspension of the yeast was prepared by triturating a weighed quantity of fresh Brewer's yeast purchased from the grocery store, in normal saline solution and then making up to a definite volume. This stock suspension, added in varying amounts, was used to inoculate a series of 9 liter flasks containing raw sewage. The concentration of NaCl in all flasks was equalized by the addition of normal saline. The concentrations of yeast added ranged from 2 to 32 ounces per 500 gallons. An additional flask containing 10 per cent sludge and sewage was set up as a control.

The volume of gas produced by each of the flasks was noted and recorded at varying intervals of time. After 18 days, the control flask, containing the sewage sludge mixture had produced a total volume of 2,850 milliliters whereas none of the flasks containing the sewage yeast mixtures had produced any gas. Readings made on the 25th day showed gas volumes ranging from 2 to 40 milliliters for the yeast-sewage mixtures.

From the above, the conclusion was reached that yeast added to raw sewage alone will not stimulate digestion for at least 25 days after addition.

To further study the effect of yeast on the digestion process, the above experiment was repeated, but this time varying quantities of yeast were added in mixtures of sewage and seed sludge. The data obtained are summarized in Table 69 and plotted in Plate 29.

Since no tests were made to determine the solids characteristics of the sewage, no direct computations could be made to show the progress of digestion (as indicated by gas production) on the basis of raw volatile solids added.

This was desirable, particularly, since the volatile consumed data reported was highly variable. The curves obtained for the amount of gas produced per gram of raw volatile solids added will have the same general relationship to each other irrespective of the value used for raw volatile solids added. For this reason an approximate value was used for the raw sewage volatile solids and was obtained from the composite value given for raw sewage characteristics fed to the septic tanks on December 3, 1947.

An initial lag period of approximately 60 to 72 hours is noted in Plate 29, both for the yeast fortified mixtures as well as the sewage-sludge control. Some increase in gas production with increasing amounts of yeast was obtained which, on the basis of the raw volatile solids added, appears as a stimulatory effect. It is believed, however, that this is due more to the production of gas from the organic matter in the yeast suspension (yeast plus starch added), then to stimulation of digestion in the sewage-sludge mixture.

The test was repeated December 10, 1947, with yeast dosages varying from 4 to 32 ounces per 500 gallons, and extension of time to 168 hours. The results, summarized in Table 70 and plotted on Plate 30, are similar to those previously obtained.

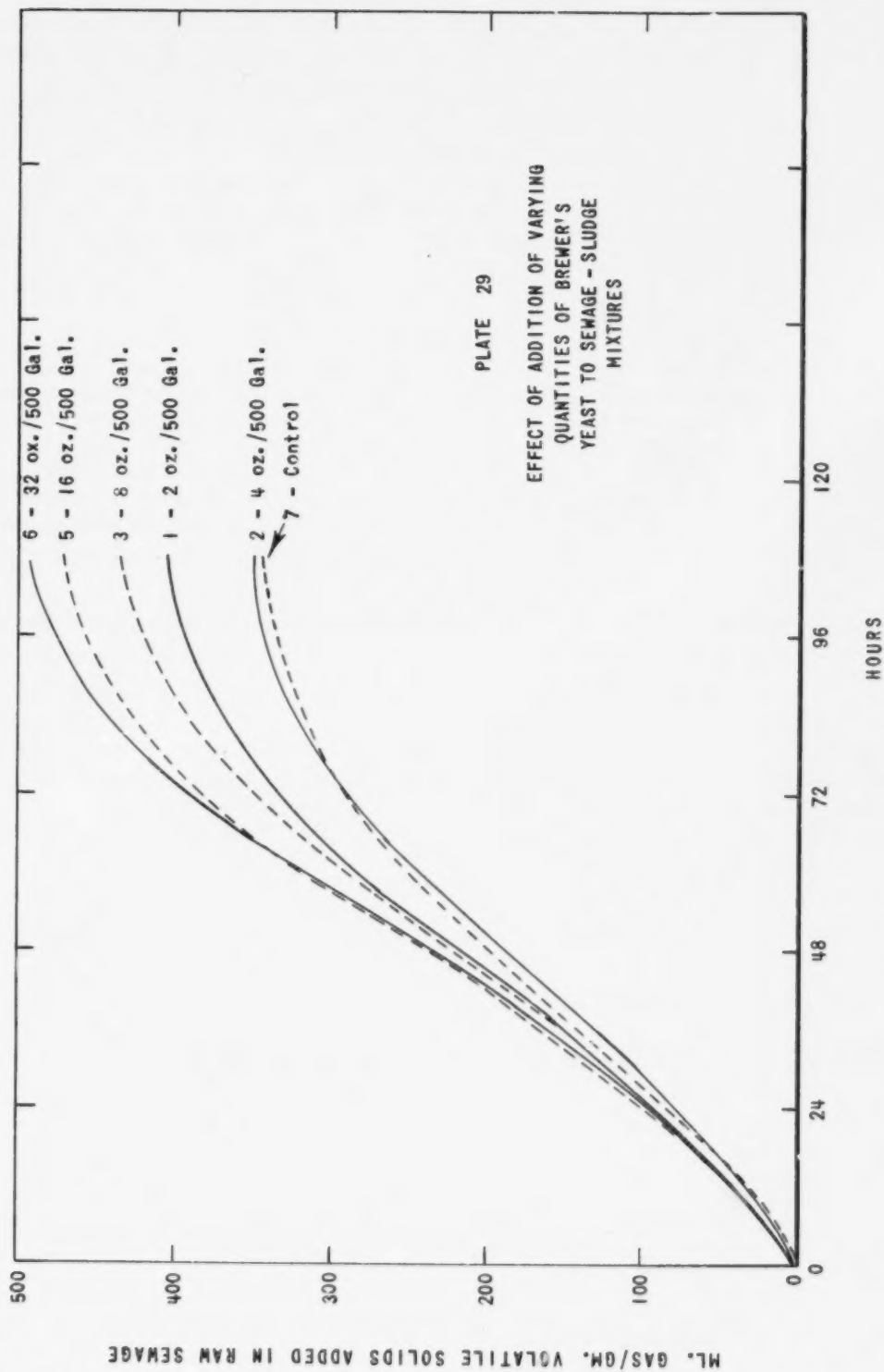
TABLE 69.--Experimental Values. Yeast-Sewage-Sludge Mixtures - II.

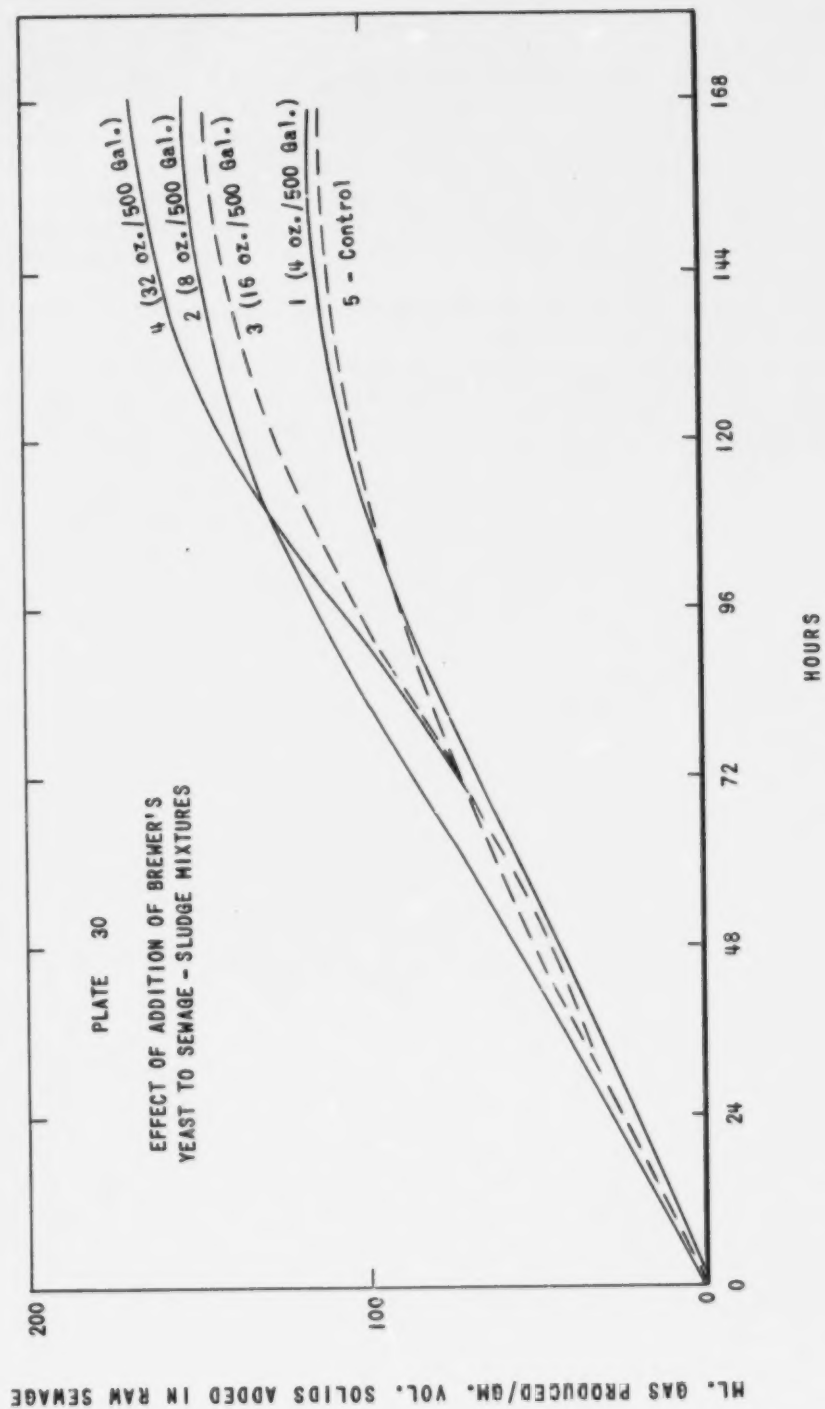
Bottle Number	1	2	3	4	5	6	7 (control)
Yeast Ounces/500 Gallons	2	4	8	16	24	32	none
Sludge - Milliliters	475	475	475	475	475	475	475
Sewage - Milliliters	8,850	8,850	8,850	8,850	8,850	8,850	8,850
Volatile Solids Consumed p.p.m.	172	200	289	394	555	359	191
Milliliters of Gas Produced	1,585	1,360	1,700	297	1,847	1,920	1,350
Milliliters of Gas Produced/ Gram Volatile Solids Consumed	972	715	620	--	350	563	742
Volatile Solids Added in R.S. Grams ¹	3.86	3.86	3.86	3.86	3.86	3.86	3.86
Milliliters of Gas Produced/ Gram Volatile Solids Added	411	352	440	--	479	497	350

TABLE 70.--Experimental Values - Yeast-Sewage-Sludge Mixtures - III.

Bottle Number	1	2	3	4	(Control)
Yeast Ounces/500 Gallons	4	8	16	32	none
Sludge - Milliliters	475	475	475	475	475
Sewage - Milliliters	8,850	8,850	8,850	8,850	8,850
Raw Volatile Solids Consumed p.p.m.	295	331	468	412	429
Milliliters of Gas Produced	730	950	920	1,050	720
Milliliters of Gas Produced/Gram Volatile Solids Consumed	261	302	207	268	176
Raw Volatile Solids Added ¹	6.25	6.25	6.25	6.25	6.25
Milliliters of Gas Produced/Gram Volatile Solids Added	117	152	147	168	115

¹For purposes of illustration only, not true value of volatile solids in raw sewage added.





Summary

1. Bottle experiments indicate that a sewage volatile solids to ripe sludge volatile solids ratio of 1 to 4.4 will reduce the lag in start of digestion.

2. In that digestion proceeds slowly at lower temperatures it appears advantageous to seed tanks placed in operation in northern climates. Also, to avoid risking a period of malodorous operation until alkaline digestion is established, seeding appears advantageous.

3. On the basis of the sludge used in the experiments about 6 gallons of digested sludge per capita would be required as a starter. Additional investigation is needed to fortify this observation.

4. On the basis of bottle experiments the addition of yeast to sewage does not stimulate digestion for at least 25 days.

5. Addition of yeast to sewage-ripe sludge mixtures appeared to have a stimulating effect on gas production. This was believed due more to production of gas from the organic matter in the yeast suspension (yeast plus starch) than to stimulation of digestion in the sewage-sludge mixture. As indicated above, ripe sludge alone is adequate as a starter.

SECTION F

EXPERIMENTAL INVESTIGATION EFFECT OF ZEOLITE SOFTENER SALTS ON DIGESTION

EXPERIMENTAL INVESTIGATION EFFECT OF ZEOLITE SOFTENER SALTS ON DIGESTION

To determine the effect of the addition of quantities of regenerative wastes to septic tanks serving homes equipped with zeolite softening units, studies were initiated on a laboratory scale wherein calcium, magnesium and sodium salts were added to seeded digestion flasks.

A concentrated stock solution containing the proper concentration and ratio of NaCl, CaCl₂ and MgCl₂ was prepared and various quantities of this stock salt solution were added to a series of bottles containing sludge and sewage. One bottle of each series served as a control. The production of gas was used as a measure of digestion in these and all subsequent experiments.

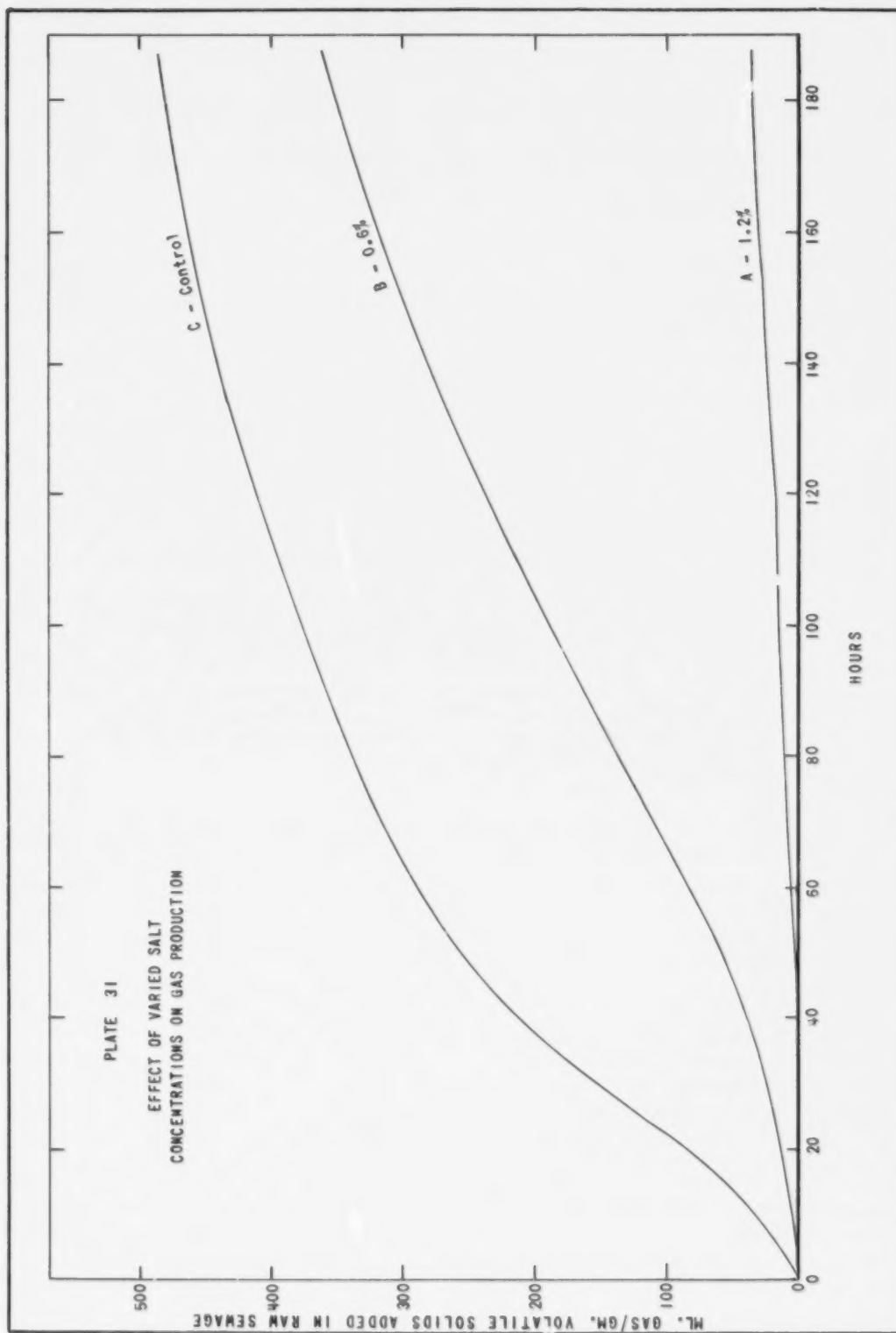
Two preliminary tests were run, in the first of which two concentrations of salt were used, one at the estimated toxic level, the other at one half this level. In addition a sludge-sewage control containing no salt was set up. The rate of gas production and cumulative gas production was noted and recorded. The results of this experiment are given in Table 71 and plotted in Plate 31 and show that the experiment was of too short duration to show the full effect of the addition of salts. However, the toxic effect of a 1.2 per cent salt mixture is quite evident. Bacteriological determinations for total coliform counts were made at the conclusion of the study. These show an increase in total number of organisms per milliliter with a decrease in salt content. The highest coliform count was obtained for the highest salt concentration; the lower salt concentration and control having the same value.

The procedure outlined above was modified somewhat in the second preliminary series in that after setting up a series of 5 bottles having salt dosages corresponding to 1.2, 0.8, 0.4, 0.2 and 0.0 per cent, the salt concentration was reduced by dilution. At regular intervals, a portion of the mixture in the digestion flasks was siphoned out and replaced with fresh raw sewage. In this series, 9 liters of sewage was added to each of the flasks, with the exception of the control, in increments of 1 or 2 liters during 6 feeds. This was done to stimulate action in a septic tank where the initial salt concentration might be diluted with and flushed out by the incoming raw sewage.

TABLE 71.--Softener Salts Experiment. Analytical Data

Bottle Number	1	2	3
Milliliter of sludge used	2,530	2,530	2,530
Magnesium chloride grams	11.86	5.93	0
Calcium chloride grams	17.78	8.89	0
Sodium chloride grams	84.36	42.18	0
Raw Sewage added in milliliter	6,570	6,770	6,970
Raw volatile solids content of mixture at start	5,055	4,376	3,376
Raw volatile solids content of mixture at end	4,734	3,786	2,391
Raw volatile solids consumed p.p.m.	321	590	985
Total volume of gas produced milliliter	137	1,379	1,882
Milliliter gas/gram volatile solids consumed	45	246	201
Raw volatile added assumed value ¹ (555 p.p.m.)	3.65	3.76	3.87
Milliliter gas/gram volatile solids added	37.6	367	512
Total bacterial count per milliliter after 188 hours of digestion	0.216x10 ⁶	2.2x10 ⁶	9.5x10 ⁶
Coliform count per milliliter after 188 hours digestion	1.0x10 ⁵	0.24x10 ⁵	0.24x10 ⁵
pH at end	8.3	8.3	8.3

¹Based on raw sewage values added to tanks July 1, 1947.



The results obtained are shown in Plate 32 and Table 72. The composite sewage added had a volatile solids content of 469 p.p.m. and, as 9 liters of sewage were used for flushing, it was assumed that the initial volatile solids content was completely displaced.

In this series pH values were recorded at frequent intervals and are noted in Table 73, along with bacteriological data taken at the same time. The latter are not too significant in that aerobic counts were made for bacteria in an anaerobic process.

The curves plotted in Plate 31 appear to be rather erratic and seem to show lag periods approaching 200 or more hours. The data presented for curve T, 3 appear to be somewhat erratic. One conclusion, however, may be drawn from these curves and that is that initial concentrations of the toxic level do not appear to have any greater effect on digestion than those at sub-toxic levels provided that flushing does occur thus reducing initial concentrations appreciably. In addition, these data indicate that sub-toxic doses appear to be somewhat stimulatory to biological life present in the digestion flasks resulting in greater gas production.

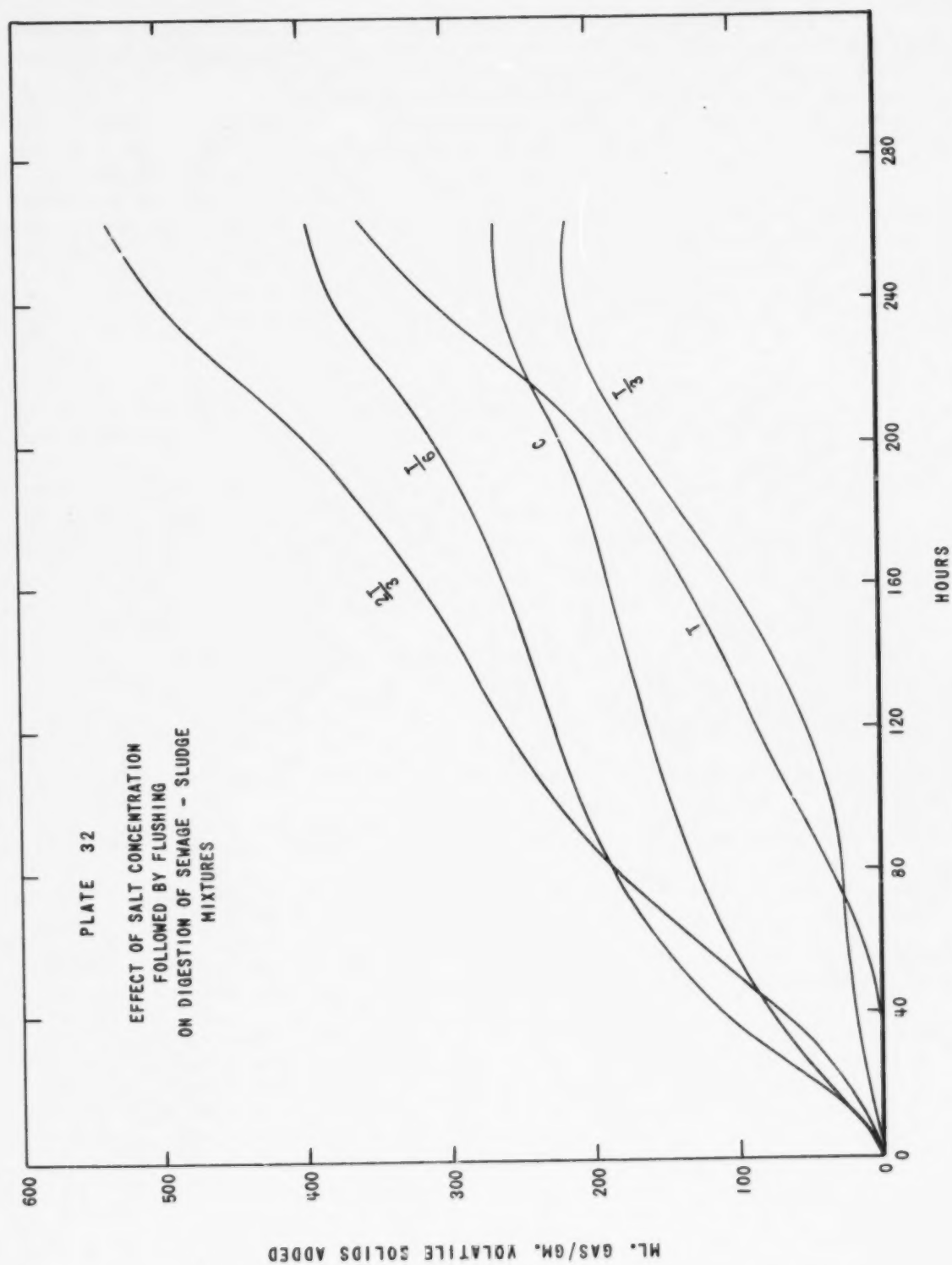
TABLE 72.--Softener Salt Experiment - Analytical Data

Bottle Number	1	2	3	4	5
Concentration of salt per cent	1.2	0.8	0.4	0.2	0
Volume sludge used in milliliter	3,000	3,000	3,000	3,000	3,000
Volume sewage added initially - milliliter	6,200	6,333	6,467	6,533	6,600
NaCl - molarity	0.1516	0.1011	0.0505	0.0253	--
MgCl ₂ - molarity	0.0131	0.0087	0.0044	0.0022	--
CaCl ₂ - molarity	0.0160	0.0106	0.0053	0.0026	--
Volume sewage used for flushing - milliliter	9,000	9,000	9,000	9,000	9,000
Volatile matter in raw sewage grams	3.12	3.18	3.25	3.29	3.32
Gas production - milliliter	1,133	1,699	700	1,308	890
Milliliter gas per gram volatile solids added	363	534	215	398	268

TABLE 73.--Bacteriological Data and pH

Date		1		2		3		4		5	
		pH	T.C. ¹	pH	T.C.	pH	T.C.	pH	T.C.	pH	T.C.
Initial mixture	July 21	6.6	22x10 ⁶	6.6	50x10 ⁶	6.6	40x10 ⁶	6.6	25x10 ⁶	6.6	14x10 ⁶
After flushing	July 21	6.8	11x10 ⁶	6.8	33x10 ⁶	6.8	25x10 ⁶	6.8	30x10 ⁶	6.9	18x10 ⁶
	July 22		5x10 ⁶		8x10 ⁶		3x10 ⁶		6.5x10 ⁶		5.5x10 ⁶
9:15 a.m.	July 23	6.9	5.9x10 ⁶	6.4	10x10 ⁶	6.4	3.6x10 ⁶	6.4	3.4x10 ⁶	7.2	6.0x10 ⁶
8:00 a.m.	July 24	6.7	4.0x10 ⁶	6.7	2.3x10 ⁶	6.6	3.3x10 ⁶	6.6	1.7x10 ⁶	6.7	1.5x10 ⁶
9:00 a.m.	July 25	6.4	3.0x10 ⁶	6.2	3.4x10 ⁶	6.0	1.63x10 ⁶	6.0	1.2x10 ⁶	6.0	2.7x10 ⁶
10:00 a.m.	July 26	6.6	1.14x10 ⁶	6.6	0.77x10 ⁶	6.3	2.1x10 ⁶	6.3	2.25x10 ⁶	6.3	6.3x10 ⁶
9:00 a.m.	July 27		1.0x10 ⁶		2.9x10 ⁶		1.1x10 ⁶		0.9x10 ⁶		2.5x10 ⁶
9:00 a.m.	July 28	6.3	1.7x10 ⁶	6.3	2.4x10 ⁶	6.1	1.9x10 ⁶	6.1	3.3x10 ⁶	6.1	0.9x10 ⁶
	July 29	6.3		6.0		6.0		6.0		6.0	
	July 30	6.0		5.7		5.6		5.6		--	
	July 31	5.8		5.5		5.6		5.6		5.6	

¹T.C. total count 1 milliliter after 24 hours incubation through July 22. 48 hours incubation from July 23 through July 28.



The flushing experiment was repeated a second time and the data obtained are summarized in Table 74 and plotted in Plate 33. The curves shown are based upon an assumed raw sewage volatile solids value, because the volatile solids present was a mixture of the sludge, initial sewage and flushing sewage volatile solids. What quantity of each remained after flushing is unknown. However, the curves do show that there is less variation in gas production because of the lower concentration of solids resulting from flushing. These curves are less erratic than those plotted for the previous series.

As the data presented thus far are relatively inconclusive, additional experiments were planned, but with some modifications. First, confirmation was sought for the toxic dose established. Once this value was determined, it was then planned to repeat the flushing experiments, but, instead of siphoning out representative quantities of the mixture at stated intervals of time and replacing the quantities removed with fresh sewage, the mixtures were to remain in contact with various salt concentrations for stated periods of time, after which the supernatant liquor would be replaced with fresh raw sewage.

The procedure utilized is described below. In all cases duplicate bottles were set up and duplicate tests made throughout in order to reduce experimental and sampling errors. To a series of 19 liter carboys, 5 per cent sludge (by volume) was added for seeding, followed by approximately 14 liters of fresh raw sewage that had passed through a 6 mesh standard screen. A varied amount of a mixture of salts (NaCl , CaCl_2 and MgCl_2) was added to each carboy in the series except 1 (the control). Distilled water was added to maintain a constant volume for the salt solution added. The carboys were then filled to the 19 liter mark with screened fresh raw sewage. After shaking, the carboys were connected to dispensing burettes for gas collection and measurement, and allowed to remain for specific time intervals. At the end of 2 hours, 16 liters of supernatant liquor was removed from one of the carboys and replaced with 16 liters of fresh screened raw sewage. The carboy contents were then thoroughly shaken and divided into 2 fractions each placed in a 9.5 liter serum bottle. Samples for analysis were taken of the supernatant liquor removed, the screened fresh raw sewage, and of each of the mixtures in the serum bottles. Each of the serum bottles was connected to an inverted dispensing burette for gas collection and measurement. The process was repeated for another carboy after 4 hours contact with the salt solution, 8, 16, 24, and 48 hours for concentrations of 1.2 per cent salt, and at 8, 24 and 48 hours for a salt concentration of 2.4 per cent. The control sample carboys containing sewage and sludge alone were divided into 2 portions and connected to the gas collecting burettes.

TABLE 74.--Softener Salt Experiment. Analytical Data

Bottle Number	1	2	3	4	5
Concentration of salt per cent	1.2	0.8	0.4	0.2	0
Sludge added - milliliter	3,000	3,000	3,000	3,000	3,000
Sewage added - milliliter	6,200	6,333	6,467	6,533	6,600
NaCl - molarity	0.1516	0.1011	0.0505	0.0253	--
MgCl_2 - molarity	0.0131	0.0087	0.0044	0.0022	--
CaCl_2 - molarity	0.0160	0.0106	0.0053	0.0026	--
Volume sewage used for flushing - milliliter	8,000	8,000	8,000	8,000	8,000
Volatile matter in raw sewage grams ¹	1.904	1.904	1.904	1.904	1.904
Gas production - milliliter	670	1,910	1,380	1,595	1,680
Milliliter gas/gram of volatile solids added	352	1,002	725	836	881

¹Assumed value based on flushing sewage.

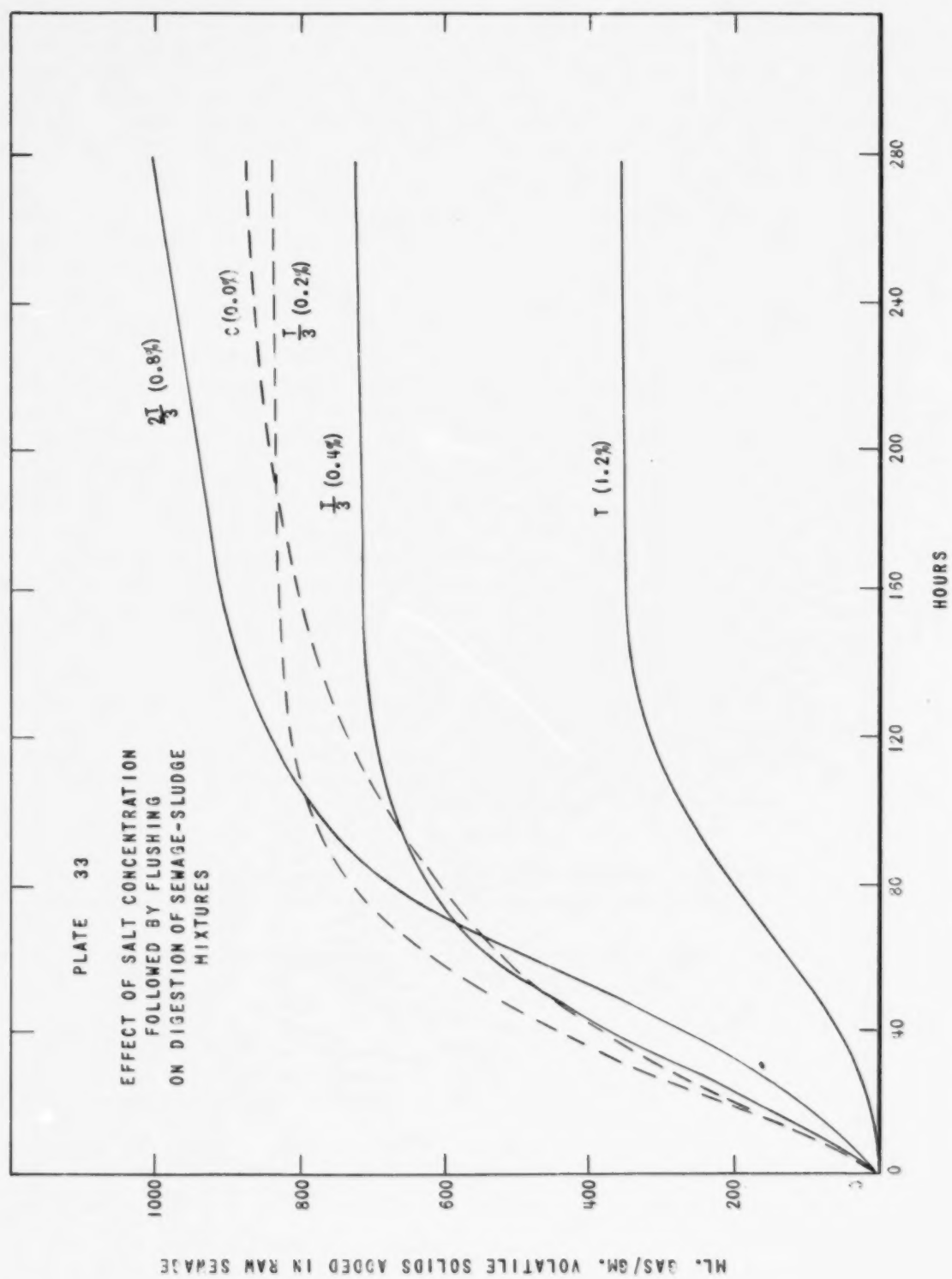


Table 75 presents analytical data collected during the experiment to study the effect of various concentrations of salt on digestion of sewage sludge mixture. Included in this table are the results of alkalinity, ammonia-nitrogen, pH, B.O.D. determinations, and bacteriological examinations. The values for alkalinity show that with a decrease in salt concentration there is an increase in alkalinity both before and after the digestion period, and that the alkalinity values were higher after digestion than before. With the exception of the values for the 2.T (2.4 per cent) concentration data (Bottle A), a 2.4 and 2.5 fold increase occurred in alkalinity during the digestion process. There was an increase in pH during the digestion from an initial value of 7.0-7.4 to 7.7. There was a 2.5 fold increase in the ammonia-nitrogen value after digestion as compared to the initial value in all cases except which had a 0.2 per cent concentration of salt.

In all cases but 1 (A - 1.2 per cent salt concentration), the B.O.D. removals were equal to or greater than those reported for the control bottles.

As noted in the Table 75 there was a reduction of 81-86 per cent in the total numbers of bacteria per milliliter in the bottles to which salt had been added and of only 55 per cent in the control bottle. Coliform reductions were greater than 98 per cent. The difference noted between the control and the other bottles for total count reductions may or may not be significant. Much weight should not be given to this difference because the results are based on only one series of tests.

In Plate 34, the amount of gas produced in milliliter per gram of raw volatile solids added is plotted as a function of elapsed time. The value for raw sewage volatile solids was assumed from raw sewage data added to the septic tanks during the period April 5 to 7, 1948. Even though the curves are not based on true values the differences will be somewhat similar irrespective of the value used for the raw sewage volatile solids added. The data presented indicate that, in general, there is a reduction in the amount of gas produced per gram of raw sewage volatile solids added with an increase in salt concentration. The salts probably do not destroy the organisms responsible for digestion, since the total counts at the end of the digestion process are almost constant in all units irrespective of salt concentration, but affect their activity. The majority of the organisms remain dormant, particularly those largely responsible for producing gas, as evidenced by the very small amount of gas produced at high salt concentrations. Salt concentrations of 0.2 to 0.4 per cent, appear to have no detrimental effect on gasification; the latter producing a little more gas than the control. Initial lag periods of about 100 to 150 hours are indicated.

Having established that concentrations of 1.2 and 2.4 per cent of the salt mixture appeared to be relatively toxic, at least during the period of observation referred to above, additional experiments were set up in which the salt concentrations were removed after varying periods of contact as outlined previously. Studies of the effect on the 1.2 and 2.4 per cent concentrations were made.

In the first series, 16 liters of supernatant liquor was siphoned from the carboys containing 1.2 per cent salt after contact periods of 2, 4, 8, 16, 24 and 48 hours, replaced with fresh raw sewage and set up in duplicate to observe the amount and rate of gas production. In the second series, 16 liters of supernatant liquor was siphoned from carboys containing 2.4 per cent salt after 8, 24, and 48 hours, replaced with fresh raw sewage, and set up in duplicate to observe the amount and rate of gas production.

The analytical data collected during the first series are presented in Table 76 and those during the second series in Table 77. A study of Table 76 shows that on the basis of gas production per gram of volatile solids consumed the results are somewhat variable, ranging from 481 to 1,100 milliliters without relation to the salt content. However, on the basis of gas produced per gram of volatile solids added there is little variation in the data for the salt bottles, ranging from 500 to 587. The lowest yield was obtained for the control tanks. In this series, two additional controls were set up on the sludge used for seeding. In one of the units the sludge was suspended in formula "C" water and in the other in distilled water. Gas production was negligible in either of these units and it may be concluded that the sludge by itself was relatively stable as evidenced by gas production. There was no apparent decrease in volatile solids in these units and the B.O.D. reductions were small or absent.

TABLE 75.--Softener Salt Experiment - Analytical Data

Bottle Number	A	B	C	D	E	F
Salt concentration	2T (2.4%)	IT (1.2%)	2/3 T (0.8%)	T/3 (0.4%)	T/6 (0.2%)	(%)
Salt solution - milliliter	800	400	266.6	133.3	66.7	--
Distilled water - milliliter	--	400	533.4	666.7	733.3	800
Sludge - milliliter	475	475	475	475	475	475
Sewage - milliliter	8,325	8,325	8,325	8,325	8,325	8,325
Raw sewage volatile solids consumed - p.p.m.	Increase	214	762	448	410	483
Average gas production - milliliter	92	487	1,821	2,824	2,665	2,654
Milliliter gas gram volatile solids consumed	--	239	249	657	678	572
Raw sewage volatile solids added - grams (assumed value)	4.62	4.62	4.62	4.62	4.62	4.62
Milliliter gas/gram volatile solids added	20	105	394	612	576	573
Hours digestion	358	358	358	358	358	358
Alkalinity - p.p.m. start	128	112	133	140	145	150
Alkalinity - p.p.m. end	205	284	314	346	352	366
pH - start	7.4	7.0	7.2	7.1	7.1	7.2
pH - end	7.7	7.7	7.7	7.7	7.7	7.7
Ammonia - nitrogen p.p.m. start	18	18	18	18	14	18
Ammonia - nitrogen p.p.m. end	45	45	45	45	45	45
5-day B.O.D. p.p.m. start	742	824	712	759	754	655
5-day B.O.D. p.p.m. end	566	418	337	374	269	340
Reduction in B.O.D. per cent	24	49	53	51	64	48
T.C. 48 hours 37°C per milliliter start	2.3x10 ⁶	3.4x10 ⁶	3.6x10 ⁶	3.6x10 ⁶	3.0x10 ⁶	1.0x10 ⁶
Coliform MPN/100 milliliter 48 hours 37°C - start	11.0x10 ⁵	3.5x10 ⁵	0.93x10 ⁵	1.67x10 ⁵	1.67x10 ⁵	1.67x10 ⁵
T.C. 48 hours 37°C per milliliter end	0.44x10 ⁶	0.47x10 ⁶	0.52x10 ⁶	0.50x10 ⁶	0.54x10 ⁶	0.45x10 ⁶
Coliform MPN/100 milliliter 48 hours 37°C - end	0.15x10 ⁵	0.68x10 ⁵	0.0053x10 ⁵	0.017x10 ⁵	0.01x10 ⁵	0.043x10 ⁵

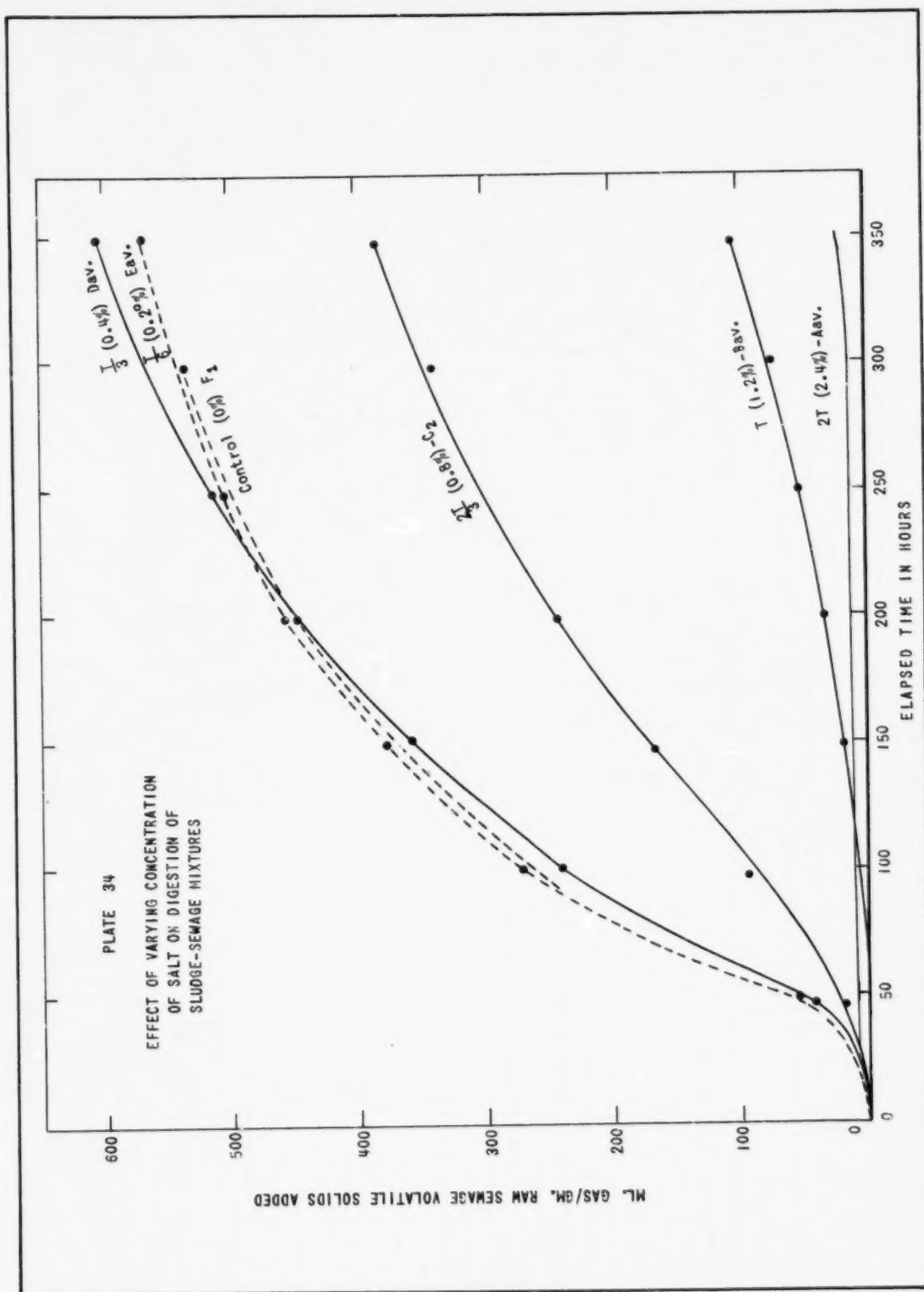


TABLE 76.--Softener Salt Experiment - Analytical Data

Bottle Number	A	B	C	D	E	F	G	H	I
Salt concentration - per cent	0	0	0	1.2	1.2	1.2	1.2	1.2	1.2
Time of contact - hours	0	0	0	2	4	8	16	24	48
Sludge volume - milliliter	900	900	900	900	900	900	900	900	900
Sewage volume - milliliter	17,100	0	0	16,350	16,350	16,350	16,350	16,350	16,350
Salt solution - milliliter	0	0	0	750	750	750	750	750	750
Distilled water - milliliter	0	17,100 ¹	17,100	0	0	0	0	0	0
Average raw volatile solids consumed - p.p.m.	274	sl. inc.	sl. inc.	407	419	542	592	248	307
Average gas produced - milliliter	1,535	--	--	2,153	1,976	2,096	2,050	1,982	1,548
Milliliter gas per gram raw volatile solids consumed	728	--	--	734	654	538	481	1,110	700
Raw sewage added - grams	3.36	--	--	3.68	3.68	3.68	3.68	3.96	2.98
Milliliter gas per gram raw volatile solids added	458	--	--	587	538	570	559	500	538
Hours digestion	472.25	472.25	472.25	472.25	472.25	472.25	472.25	472.25	472.25
Alkalinity - start p.p.m.	326	144	132	249	264	260	223	310	312
Alkalinity - end p.p.m.	515	198	176	523	519	520	514	516	524
pH - start	7.3	7.2	7.1	7.4	7.3	7.6	7.4	7.6	7.5
pH - end									
Ammonia nitrogen - start	44	18	20	40	40	40	30	48	52
Ammonia nitrogen - end	54	30	24	66	68	64	64	64	64
5-day B.O.D. - start	562	278	208	742	688	684	677	708	673
5-day B.O.D. - end	238	242	253	237	281	298	282	298	306
5-day B.O.D. - reduction per cent	58	13	inc.	68	59	56	58	58	55

¹Formula "C" water.

A general increase in alkalinity was noted at the start of the run with an increase in the contact time with the salt solution, ranging from 249 to 312 p.p.m. for contact time of 2 to 48 hours, respectively. The control tank had the highest alkalinity 326 p.p.m. There was an increase in alkalinity during the digestion process, but the increase ratio was not as constant as in the previous run, ranging from 1.3 to 2.3. With the exception of the sludge control tanks, the ammonia nitrogen values were relatively constant. The final values were even more constant and an increase in ammonia nitrogen was noted as a result of digestion. The increase ratio ranged from 1.2 to 2.1. B.O.D. reductions were fairly constant varying from 55 to 68 per cent. There was a slight tendency toward a decrease in initial B.O.D. with an increase in contact time and an increase in final B.O.D. with an increase in contact time.

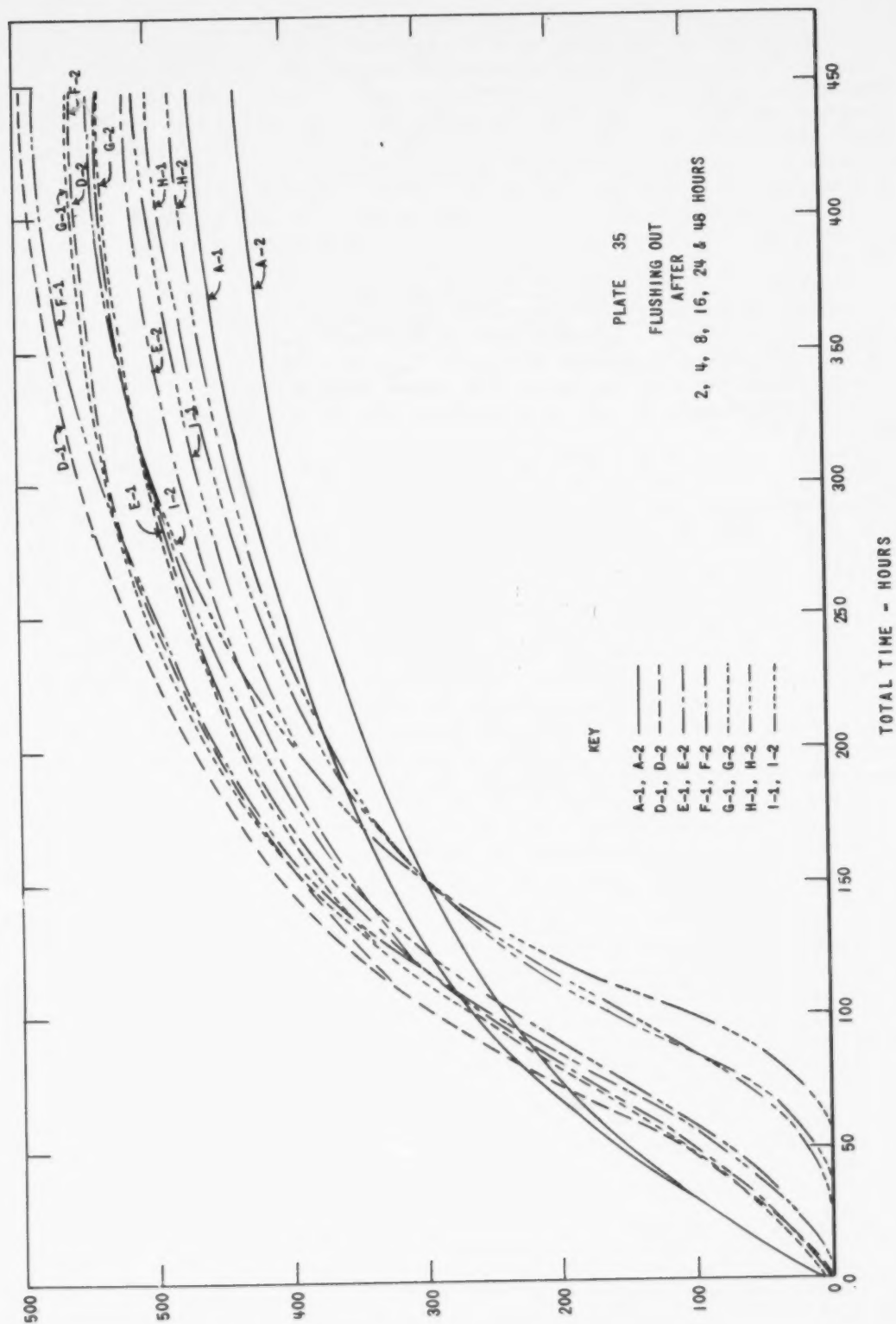
The control values indicated in Table 76 should not be given too much weight since in order to obtain proper control it would have been advisable to have a control unit for each contact period. In that way each control would have been subjected to the same treatment (siphoning off supernatant and replacing with fresh raw sewage, etc.) and the results between each pair would have been comparable. The control tank only indicates in a general way the differences to be expected due to the addition of salt and of maintaining certain contact times.

In Plate 35, the gas produced per gram of raw volatile solids added is plotted as a function of elapsed time. In general, the curves indicate that for salt concentrations of 1.2 per cent, the removal of a major portion of this concentration (about 84 per cent in our case) after time intervals of 2 to 48 hours has no appreciable effect upon the ultimate gas production per gram of volatile solids added, and that full recovery results in less than 200 hours. However, there is an increase in the lag phase with an increase in contact with salt up to about 200 hours for 48 hour contact time.

Another series of 4 units was set up to determine the effect on digestion of contact for 8, 24 and 48 hours with a 2.4 per cent concentration of salt. The results of this series are given in Table 77. Here again as in most previous instances there is considerable variation in the gas produced per gram of volatile solids consumed, but there appears to be a decrease in gas production with an increase in contact time, the range being 485 to 1,310. The same relationship is borne out with the gas production per gram of raw volatile solids added, but the variation is not as marked, the range being 456 to 522.

TABLE 77.--Softener Salt Experiment - Analytical Data

Bottle Number	J	K	L	M
Salt concentration - per cent	0	2.4	2.4	2.4
Time of contact - hours	0	8	24	48
Sludge volume - milliliters	900	900	900	900
Sewage volume - milliliters	17,100	15,600	15,600	15,600
Salt volume - milliliters	0	1,500	1,500	1,500
Average raw volatile solids consumed - p.p.m.	480	280	351	355
Average gas produced - milliliters	2,088	2,636	1,720	1,240
Milliliter gas per gram raw volatile solids consumed	565	1,310	680	485
Raw sewage added - grams	4.73	5.05	3.58	2.72
Average milliliters gas per gram raw volatile solids added	443	522	480	456
Hours digestion	407.5	407.5	407.5	407.5
Alkalinity p.p.m. - start	354	190	224	214
Alkalinity p.p.m. - end	677	465	546	488
pH - start	7.5	7.2	7.4	--
pH - end	7.3	7.3	7.4	7.5
Ammonia nitrogen p.p.m. - start :	48	24	36	36
Ammonia nitrogen p.p.m. - end	81	35	72	62
5-day B.O.D. p.p.m. - start	625	693	652	570
5-day B.O.D. p.p.m. - end	450	385	339	312
5-day B.O.D. reduction - per cent	28	44	48	45



There has been an increase in alkalinity following digestion as in the previous cases and the ratio of increase ranged from 1.9 to 2.4.

The 3 salt tanks had practically a constant increase ratio at 2.3 to 2.4. There was no appreciable change in pH during the digestive process. The ammonia nitrogen values showed an increase, but the increase ratio was not constant, ranging from 1.5 to 2.0. The B.O.D. reduction in the control sample was low; 28 per cent reduction being noted. B.O.D. reductions in the contact flasks were practically constant with reductions of 44 to 48 per cent obtained.

In Plate 36 gas production per gram of raw volatile solids added is plotted as a function of time. The significant feature of this curve is that the lag phases of the curves are much more marked with an initial salt concentration of 2.T (2.4 per cent) than they were at 1.T (1.2 per cent), extending up to 250 hours. There is little difference in the ultimate values for gas production.

Curves of the type presented in Plates 35 and 36 are the same general form as the type which fits the B.O.D. reaction and other unimolecular forms. The specific equations for each of the curves in these figures and several others were computed by the Thomas Slope Method and the theoretical values checked very closely with the observed values. The equations are of the form

$$y = X_0 + (1-x_0) \left[1 - 10^{-k(T-y_0)} \right]$$

Where y = value at any time T

x_0 = initial value for gas production in series used for computing the curve

L = ultimate amount of gas produced in milliliter

k = rate constant, in $1/\text{time}$ units or $1/\text{days}$

T = time, in days

y_0 = time in days corresponding to initial value x_0

With the completion of the laboratory work described above, it was decided to add enough of the salt components to tanks 2 and 8 to provide a tank mixture having a salt concentration of 2.T (2.4 per cent). Before the salt was introduced into the tanks, some of the sludge was removed. The salt was added as a sewage solution. Additional fresh raw sewage was added to fill the tanks. During the filling process the tank contents were stirred continuously. Samples of the fresh raw sewage added, the effluent from the tanks and, at the start of each day, of the tank contents, were collected for chloride determinations. In this way a chloride balance was maintained as it was known what was in the tank, what was added, what was removed, and what remained. The pounds of chlorides remaining in tanks 2 and 8 have been plotted against volume of sewage added in Plate 37 and compared with a curve showing theoretical removal based on instantaneous mixing. These curves show that there was little mixing of the tank contents and that the incoming sewage apparently "floated" on top of the tank taking up some of the chlorides as it flowed out the effluent end of the tank. That this actually occurred is shown in Plate 38 in which chloride concentration in p.p.m. is plotted at various depths below the surface of the liquid. The results plotted were obtained after 19 days of operation during which time 3,565 gallons of sewage had been added to the tank corresponding to a volumetric displacement of more than 7.

To check whether the high salt concentration (2.5 per cent) had any detrimental effect on the sludge itself, 3 digestion flasks were set up, in duplicate, using sludge from tanks 2, 8 and 6 as seed material in the ratio of 1 part sludge to 8 parts sewage by volume. The latter sludge served as a control since it was not in contact with any salt. The results of this experiment are plotted in Plate 39 and show that the sludges themselves were affected somewhat as noted by the lag period in gas production for curves 2 and 8 but they also show that the dilute salt mixtures (having a salt conc. of about 0.3 per cent) produced much more gas than the control. These curves were prepared based upon the assumption that the raw sewage volatile solids concentration was 4.728 grams.

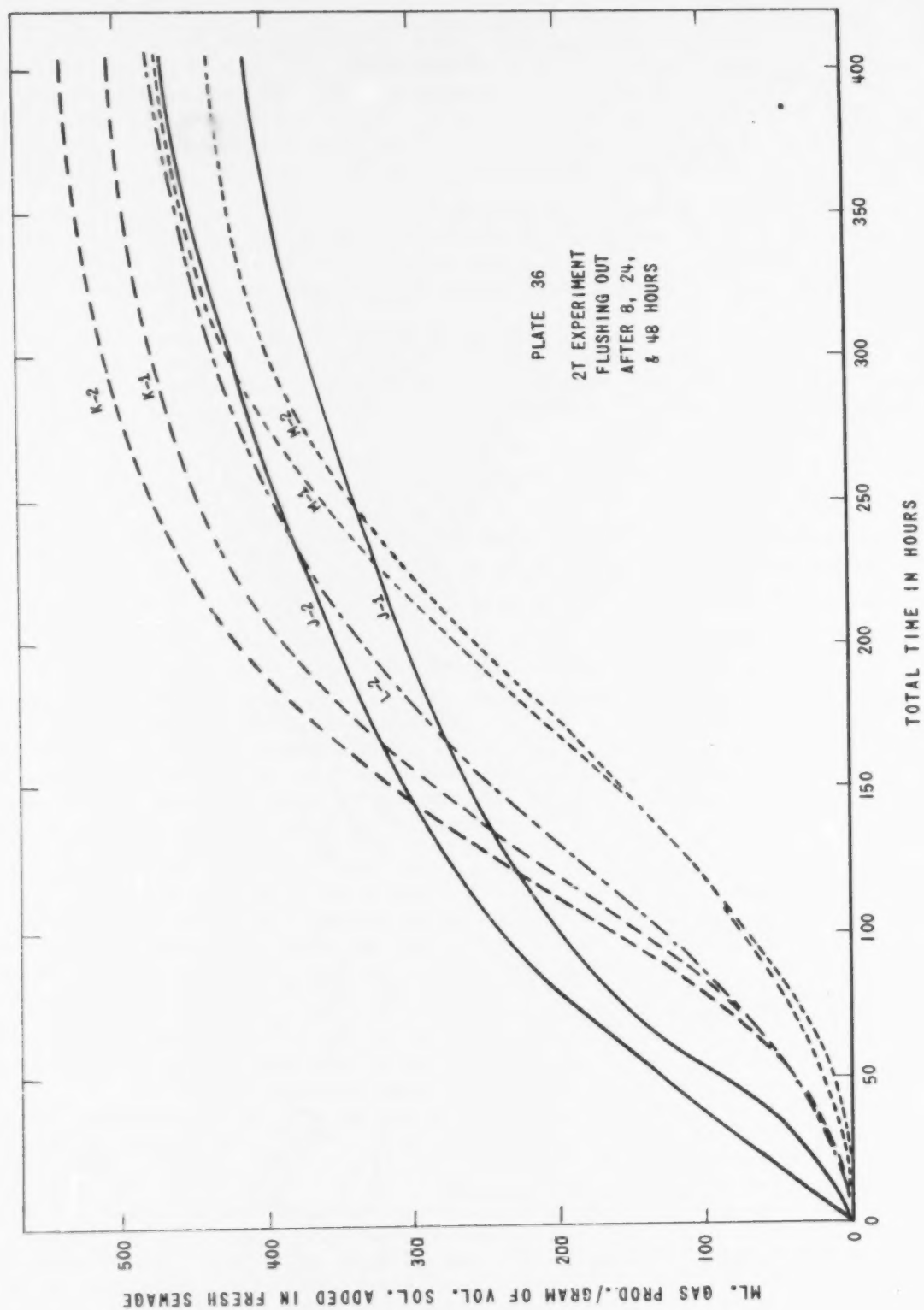
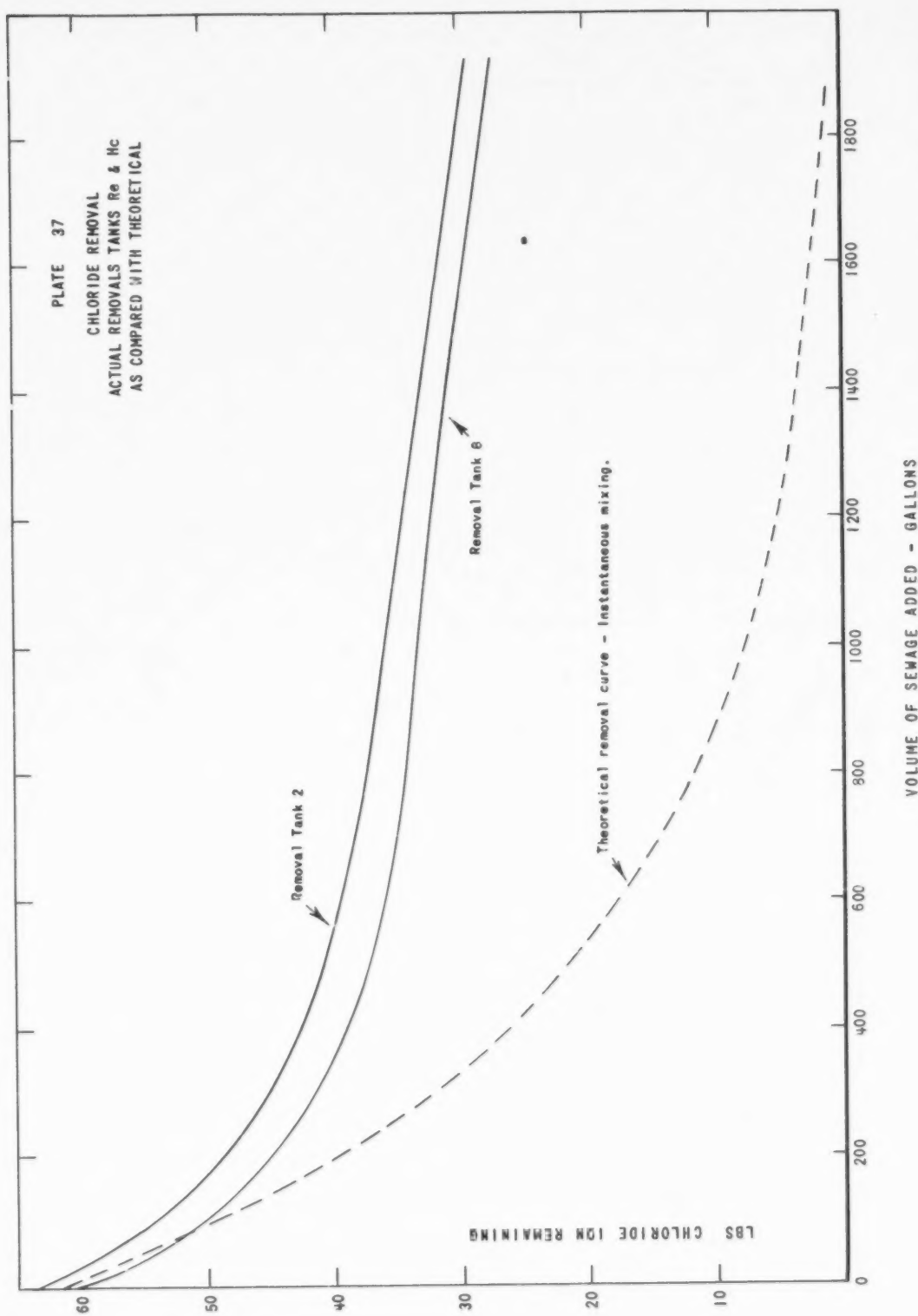


PLATE 37
CHLORIDE REMOVAL
ACTUAL REMOVALS TANKS Re & Hc
AS COMPARED WITH THEORETICAL



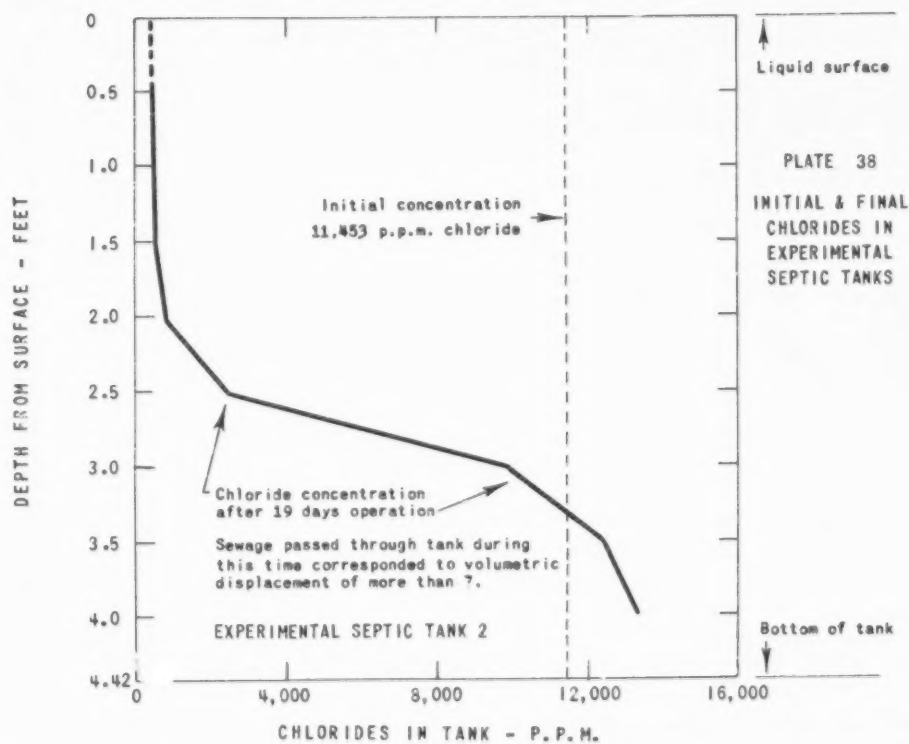
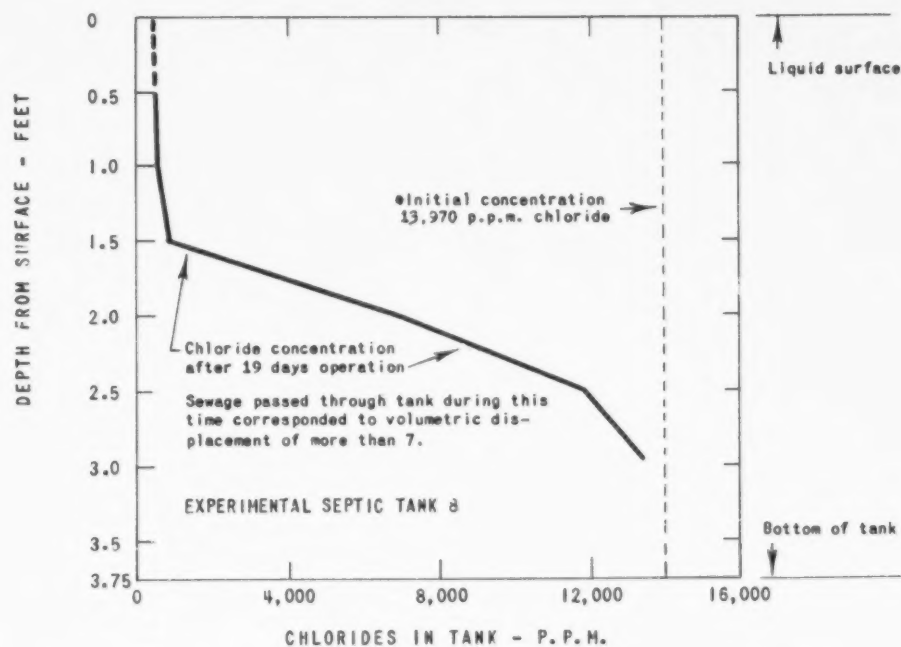
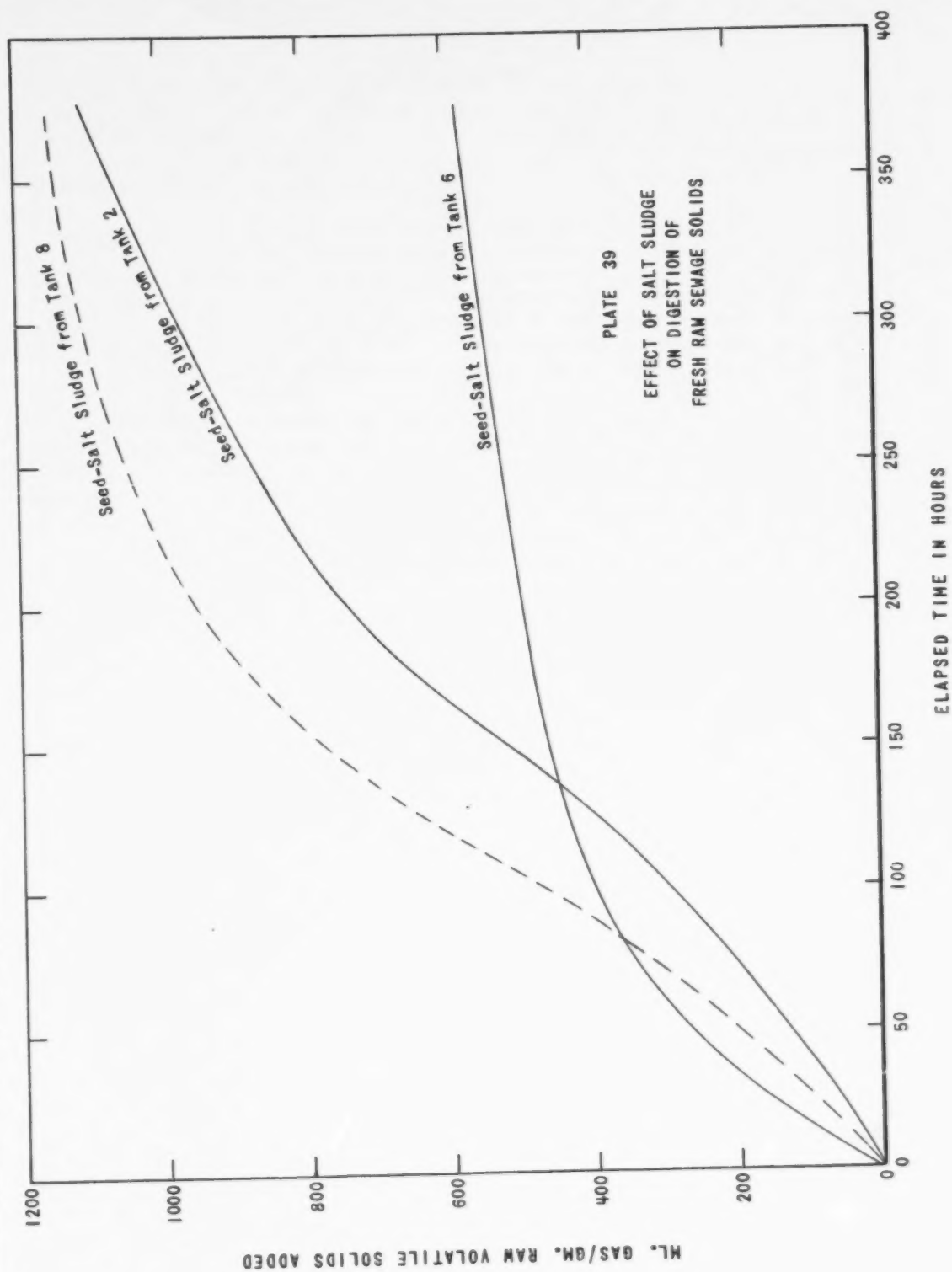


PLATE 38
INITIAL & FINAL
CHLORIDES IN
EXPERIMENTAL
SEPTIC TANKS



Summary

1. Bottle experiments tracing the course of digestion of sludge-sewage mixtures containing 0.6 and 1.2 per cent salt (NaCl , CaCl_2 and MgCl_2) concentrations respectively indicate a pronounced inhibiting effect with a 1.2 per cent salt concentration, and much less inhibiting effect with the lower concentration, during 180 hours contact. Further tests indicated that salt concentrations of 0.2 and 0.4 per cent have no detrimental effect on gasification.

2. It was further found that the effect of toxic concentrations is reduced by flushing (mixing and dilution). After 2 to 48 hours contact with 1.2 per cent salt concentration, followed by dilution, recovery from initial lags develops within 150 to 200 hours.

3. A 2.4 per cent salt concentration in tanks No. 2 and 8 failed to dilute in the lower part of the tanks when dosed at the 250 gallon per day feed rate, although mixing and dilution did take place in the upper part of the tank. With instantaneous mixing, practically all of the salt should theoretically discharge from the tanks in a week. Actually only 50 per cent of it did.

4. The tests made thus far on two full sized tanks indicate that the mixing obtained in the tanks, through intermittent discharge of sewage through the tanks, was inadequate to reduce the salt concentration in the lower part of the tanks. It appears from this that salts could accumulate at the lower levels in the tank due to repetitive salt discharges until toxic levels are reached. Tests over a longer period, with simulated repetitive discharges of salts with the incoming sewage should be carried out in this connection.

5. In sub-toxic concentrations, salts appeared to stimulate digestion.

SECTION G

SURVEY OF INFORMATION ON THE FREEZING ASPECTS
OF HOUSEHOLD SEWAGE DISPOSAL SYSTEMS

SURVEY OF INFORMATION ON THE FREEZING ASPECTS OF HOUSEHOLD SEWAGE DISPOSAL SYSTEMS

Introduction

It was anticipated early in the study, as very little information on the freezing aspects of shallow household systems in northern climates had developed from the search of literature at the time, that a field investigation might have to be made. However, as the search continued, and contacts with health authorities and plumbers in northern areas progressed, it was felt that sufficient information was available to throw probably as much light on this subject, from a practical aspect, as could be developed by anything short of an extended, and expensive, field investigation.

Review of Literature

Flood (1), reported in 1944 that ... "There has been some misconception about the necessity of placing tile in the field below frost line to prevent freezing in the New England area during the winter. A large number of such fields, in which the tile is placed on the average 18 inches below the ground surface, have been operating satisfactorily for many years." Graham (2), reporting on a temperature study of a septic tank and 2 feet deep tile field serving the Physics Building, Ontario Agricultural College at Guelph, made during the winter of 1921, found that although air temperatures dropped as low as -6° Fahrenheit no part of the system froze and the lowest tank and tile line temperatures were 34° Fahrenheit and 34° respectively; Gross (3), indicated that freezing will occur without causing difficulty and that tile field depths of 18 to 30 inches were found suitable in New Jersey; Tyler (4), reporting on Minnesota conditions, stated, ... "In rare instances frost has interfered with the action of a septic tank, but generally speaking a foot of earth cover is all that is necessary."

The State Health Department publications on design recommendations for residential sewage disposal systems in eleven northern States were examined with respect to absorption system depths, comments on freezing, or winter precautions.

Maine

Recommends that tile pipe be placed not more than 24 inches below surface. No reference to freezing or winter precautions noted.

New Hampshire

Recommends a trench depth 18 to 30 inches. Refers to Prof. Fletcher's principles (1912): "...the tank may be placed quite close to the house without likelihood of offense, and if properly constructed and cared for ... its contents will not freeze in winter." No winter precautions noted.

Vermont

Recommends that tile be laid at depth (G) 18 to 24 inches and should not average over 24 inches; one or two feet of earth fill over tank is desirable but not always necessary. No references to freezing noted.

New York

Recommends a trench depth 18 to 30 inches (Bull. 1, 1943). No reference to freezing or winter precautions.

Michigan

Recommends 12 to 20 inches cover over tile. "Virtually no trouble has been reported from either the tank or the tile system freezing when they were constructed according to the directions given." No winter precautions noted.

Wisconsin

Recommends that drainage tile be laid from 1 to 3 feet below the surface of the ground. "Investigation and experience of those using such systems indicate that septic tanks and absorption fields may be operated at shallow depths if certain requirements are rigidly observed. The requirements are as follows:

1. The absorption field whether shallow or deep must be constructed in ground which will absorb water. The more absorbent the soil the less danger there is of the field freezing.
2. The surface of the liquid in the septic tank must be a reasonable distance below the original ground level. The termination of the house drain above the ground line to provide for a head for operating a siphon and absorption field invariably results in the freezing of the liquid in the tank, dosing chamber and field tile.
3. All septic tanks, dosing chambers and disposal units and pipe lines subject to extreme frost conditions should be covered with a layer of straw at least 12 inches in thickness during the winter months.
4. The tank and absorption field must be kept in continuous use throughout the winter. If the house is left vacant for a few days or if insufficient volume of warm water is used, the system will freeze and be rendered useless until the frost goes out of the ground.

Minnesota

No depth specification, reference to freezing or winter precautions were noted. Tile lines converge to inspection manhole or seepage pit at end, with lower half last tile blocked off.

North Dakota

Preferred depth tile (bottom trench) 3 to 5 feet. Advises against placing tile closer than 3 ft. to ground surface, or deeper than 6 ft. No reference to freezing or winter precautions noted.

Montana

Recommends at least 12 inches cover over tile, but not more than 20 inches. "One authority says, The temperature of the sewage will prevent freezing, even in very severe winter weather, especially when the ground is covered with snow.' Experience in New Hampshire, Wisconsin, Maine and Montana indicate that where this tile system of distribution is used a maximum covering of 24 inches is sufficient at all times."

Idaho

Preferred depth of cover 18 inches, maximum 36 inches. No reference to freezing or winter precautions noted.

Washington

Recommends not less than 6 nor more than 24 inches cover over tile. No reference to freezing or winter precautions noted.

Recent Case Histories

Several references to engineers and sanitarians encountering freezing circumstances last winter were followed up by correspondence. The response on these is summarized below.

Two household systems froze in the winter of 1947-48 in Bay County, Michigan (Saginaw Bay region) (5). In one case a tile lead under a driveway started the freezing condition throughout the system. It was indicated that this often happens if tile is not insulated under such an area. In the second case the entire system was under lawn, with drain tile laid in stone, with an average depth of 14 inches to top of tile. The freeze-up was thought due to installation in the late fall, with possible use of some frozen back fill.

Four cases were mentioned by the Lansing-Ingham County Health Department, Michigan (6), in connection with which the following was noted:

- A. Tank installed November, 1947, on sink drain only, no earth cover over tank ...
"Freezing expected under these conditions."
- B. Tank installed late summer 1946, with tile in fine sand 18 inches below surface, but with less than one-eighth inch joint spacing and without gravel under and around tile, contrary to official advice. After good operation the first winter, a coating of clear ice up to one-fourth inch in thickness around the tile formed in the winter of 1947-48, preventing drainage from the tile. This would not have occurred with one-eighth to one-fourth inch gaps and porous underlay in the opinion of officials.
- C. Drain field installed November, 1945, in a low gravel pocket surrounded by heavy soil, gave no trouble the first 2 winters, froze in winter of 1947-48, along with the house sewer. Freezing was attributed to frost penetration of heavy soil around pocket, slowing drainage, backing up system and preventing carriage of sewage heat out into system. When tank outlet was opened the sewer thawed and no further freezing was experienced, although frost penetration was such that a water pressure line 4 feet below the surface later froze.
- D. A tank and tile system in a low pocket, surrounded by clay hills and repeatedly flooded by surface run off, installed in late summer 1946, gave drainage trouble in the summer of 1947, ceased to operate January, 1948. This was replaced with an approved system in February, using a power shovel to penetrate nearly 3 feet of frost in heavy soil. The new field was a 10 by 40 foot excavation with 12 to 18 inches coarse stone backfill under 120 feet of 4 inch tile and supplemented by 60 feet of tile in 2 foot trench with 4 inches stone below the tile. The excavation was open two weeks, during which time the entire exposed surface froze solid. The new system operated for less than 30 days before the house sewers backed up. An additional 50 feet of tile offered relief and no further trouble was reported through the remainder of the cold weather. The officials assumed that further use of the system promoted thawing of the excavated area. The systems above mentioned were the only systems approved under County Regulations in the past 5 years which gave trouble from freezing (some 1500 systems were installed in Ingham County under regulatory control put into effect in 1942).

As a result of these developments the County officials concluded the following:

- (1) That septic tanks without earth cover should not be placed in operation in winter with other than complete household sewage, without surface water or other low organic matter drainage.
- (2) That coarse gravel should be placed under and around tile regardless of the type of soil, and joint spacing should be watched closely.

- (3) That the low point on a property is not always the best location for these facilities. Locations not subject to surface drainage from surrounding slopes should be considered.
- (4) That installations in freezing weather should be avoided unless excavations can be protected against frost.

Through contacts with septic tank cleaners and repairmen in Ingham County, two of whom reported 16 calls during the winter of 1947-48, concerning frost difficulties on systems installed before County regulations were in effect, the County officials learned the following: There was interference with the freeboard space in the tanks from congestion of scum and sludge, and in most cases tanks required cleaning; tile fields were generally not affected by frost, but sewer lines, especially those under driveways, were frozen.

Other Contacts

Professor Kitching, Ontario Agricultural College (7), responded recently to an inquiry on freezing as follows: "I note that you are interested in the possibility of freezing in these tanks. We, of course, wondered about this too, and have investigated tanks which have been in operation for some years in the more northerly sections of our country. We have found that if they are kept in use continually and that no part of the system is installed under a hard-packed roadway, there has been no trouble whatsoever from freezing, that is, with the tank about 12 inches under ground and the disposal tiles laid 18 to 24 inches under ground."

Inquiry was made concerning freezing conditions in the Saranac Lake, New York, region in response to which the State District Engineer (8), indicated that in 10 years of experience in the area no requests for special advice or assistance with regard to problems arising from such installations during the winter months had been received. Usual depth of cover was thought to be not over 3 feet to the top of the septic tank, and the usual depth of tile lines, 2 feet. The frost line is frequently more than 5 feet below the surface in the area, but thawing and freezing is not common, as mid-winter thaws are seldom so extensive as to cause softening of the ground to any appreciable depth.

School System Freeze-ups

Upon notification of freeze-ups in 12, out of some 70 or more, rural schools having septic tank soil absorption systems in Calhoun County, Michigan, in early February, 1948, one of the engineers of this project accompanied the Calhoun County Sanitary Engineer in an inspection of one of the systems, about 10 miles from Battle Creek, being opened by the County Health Department. It was found that the stoppage was in the 4 inch C. I. sewer close to the school, a 32 pupil, single classroom school equipped with a classroom sink and 1 water closet each in the girl's and boy's toilets. With some 5 inches or so of snow cover in the area, the ground surface was bare to icy adjacent the school in the vicinity of the sewer. The sewer was vented to the surface through a 1-1/2 inch vertical pipe, located about 5 feet from the septic tank. Other installations were not so vented. The 18 inches of earth cover was frozen down to the sewer. In the septic tank a 1 inch ice sheet was suspended at normal water level, the water having fallen some 14 inches, possibly due to leakage, and a second 2 inch ice sheet formed there. There were neither ice nor water in the absorption tile close to the septic tank. Tap water temperature was 48° Fahrenheit (well supply), the septic tank liquid temperatures were 32° Fahrenheit beneath the 2 inches of ice, and 36° Fahrenheit at the bottom. The air temperature in the tile line, which was under 20 inches of frozen cover, was 32° Fahrenheit. The freeze-ups occurred about February 4, 1948, during a prolonged period of low temperatures, following a January with a mean temperature of 16° Fahrenheit, with daily means ranging from 30.5° Fahrenheit to - 1° Fahrenheit and daily minimums ranging from

28° Fahrenheit to -16° Fahrenheit. From January 13 through February 10, daily ranges were as follows: means, 21.5° Fahrenheit to 2.5° Fahrenheit, minimums, 11° Fahrenheit to -16° Fahrenheit, maximums, 33° Fahrenheit to 11° Fahrenheit.

Considering the icy bare surface over the sewer, that practically no heat is added to the water in the rural school, and the long daily and weekend idleness, it would appear that such school installations are particularly vulnerable and that maintenance of snow or other insulating cover is indicated where weather conditions are severe.

At two other schools in the County teachers were able to open the sewer lines by pouring salt in the stool. The complete score on the school freeze-ups is not at hand but it is known that in some cases the tile fields were frozen. Frozen school systems were also reported in adjacent Branch County, to the South, concerning which local authorities found that 2 of 3 tanks opened on systems in which plumbing facilities were not functioning properly, were frozen and apparently operating beneath the ice. The third tank had a thin scum of ice around the edges.

Inquiry was made at the time as to reports of household freeze-ups in the area. One large cleaning concern, contacted in this connection, knew of none, nor were there any in adjoining Kalamazoo County, in which City-County officials were contacted.

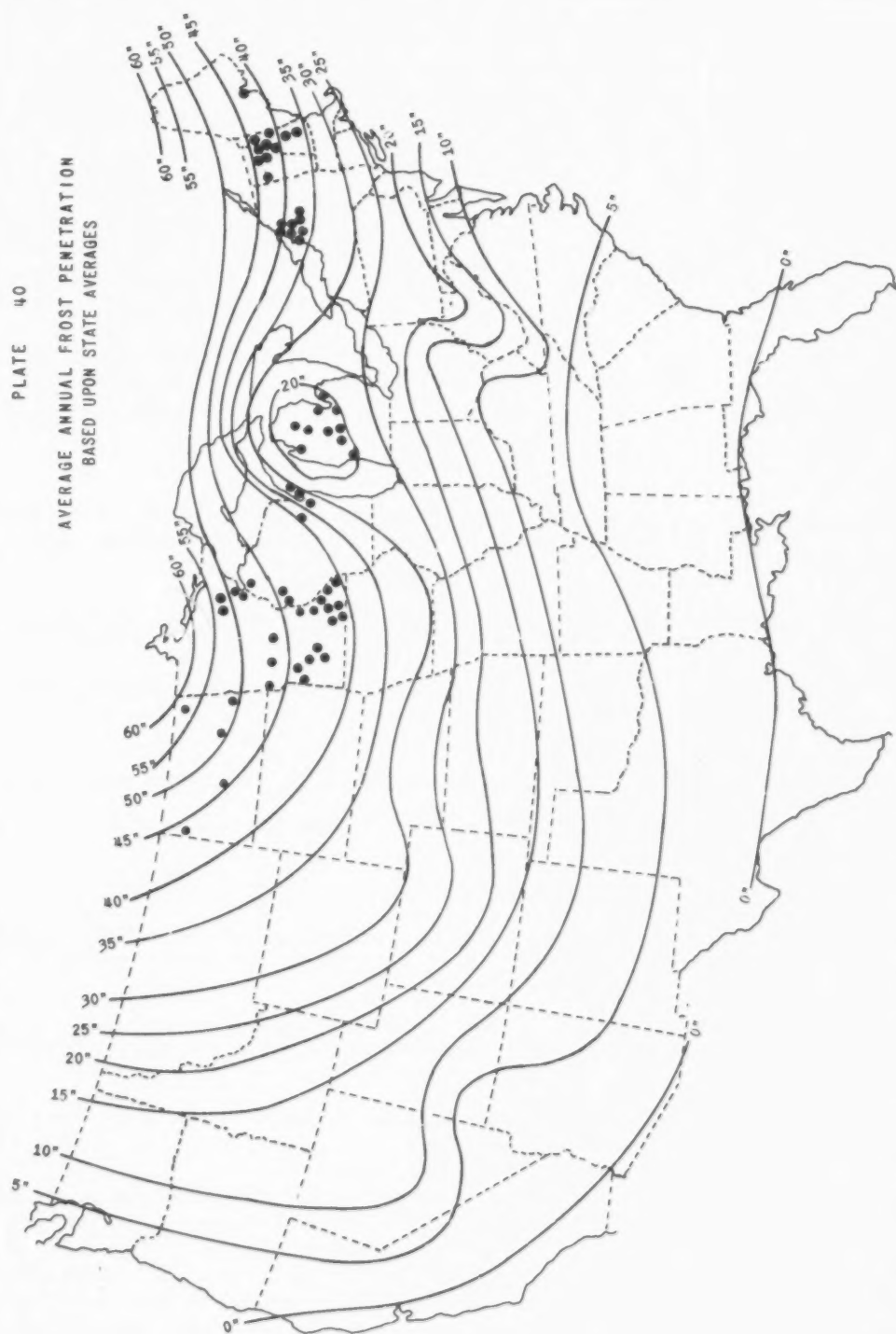
Poll of Plumbers in Northern Area

Through the cooperation of a manufacturer and several jobbers, a list of 162 plumbers located in the northern areas of this country was circularized during June and August, 1947 on the following topics:

1. What is the usual practice in installations with which you are familiar in your locality, as to the depth of the house sewer, the tank and tile field?
2. Do you know of any tile fields 18 inches to 24 inches below the ground surface?
3. Do these shallow systems freeze if in constant use?
4. What part of the system freezes first; the sewer, the tank, or the tile field?
5. Are any special precautions taken, such as covering the tank and field with hay or manure, or other measures?
6. Are dosing siphons generally used?
7. Do you know of any cases where a shallow system installed in the fall freezes the first winter and operates satisfactorily after that? What about installations made in the spring in this connection?
8. Are the lines of the absorption field vented to the ground surface? Have you found any difference in operation, with respect to freezing circumstances, between vented and unvented tile fields.

Of a total of 65 replies, 62 were tabulated for review. The geographic distribution of the 62 respondents is indicated on Plate 40 on which also is shown the average annual frost penetration for the northern section of the country.

In examining this information the replies were arranged according to geographical location in the several frost penetration zones, and further, with respect to response on question 2, "Do you know of any tile fields 18 inches to 24 inches below the ground surface?" The response on this question was: 37 yes, 18 no and 7 blank. It was felt that response to questions on freezing in shallow systems from the group answering "yes" to question 2, would be more likely to reflect first-hand experience, and the response from this group is tabulated in Table 78 and examined in the paragraphs following. The tabulation of individual response is included in Appendix E.



Traced from U. S. Dept. Commerce Weather Bureau Map.

TABLE 78.--Response of Plumbers Having Knowledge of Shallow Systems in Northern Areas

Frost penetration zone, inches	Distribution replies		Do shallow systems freeze?		What part freezes first?						Are special precautions taken?		Knowledge of fall installation freezing 1st winter only		Are absorption lines vented to surface?	
													Yes	No	Yes	No
	All (62)	This tab. (37)	Yes	No	Sew.	Tile Field	Sew. Tank TF	Tf TF	No	Yes	No	Yes	No	Yes	No	
55-60	1	0	--	--	--	--	--	--	--	--	--	--	--	--		
50-55	4	2	1	1	--	1	--	1	--	2 ¹	--	2	--	-- 2		
45-50	7	5	1	3	--	5	--	--	--	3 ²	1	1	3	1 3		
40-45	28	11	--	10	1	4	--	1	2	4	4	--	8	3 4		
35-40	9	8	1	6	2	3	1	--	1	3 ³	4	2	5	-- 6		
30-35	3	2	--	2	1	1	--	--	--	1	1	--	2	-- 2		
20	10	9	1	8	--	3	1	1	3	1	8	2	6	2 7		
Totals	62	37	4	30	4	17	2	3	6	14	18	7	24	6 24		

12 - Cover system with 8 to 10 inches manure; bank system with 3 to 4 feet of dirt.

21 - Cover tank when used in summer only.

31 - Cover outlet if open to ditch.

It may be seen from Table 78 that, in response to question 3, "Do these shallow systems freeze if in constant use?", 30 of the 37 felt that shallow systems do not freeze; 4, that they do, and the remaining 3, not responding. From the distribution on frost penetration it is seen also that the response is spread over the several frost penetration groups and not confined to the less severe conditions. Average frost penetrations of 50 inches and above prevail in the northern sections of North Dakota, Minnesota and Maine as indicated on Plate 40.

The response to question 4, "What part of the system freezes first: the sewer, the tank, or the tile field?", appears to be largely opinion, in that 30 of the 37 respondents indicate that shallow systems do not freeze, yet 26 identify part of a system which would freeze first. Examining the response with this in mind, it is seen that 17 indicated the tile field to freeze first; 4, the sewer; 2, the sewer and tile field; 3, the tank and tile field; and the remaining 11 indicated either no freezing, or made no insertion, consistent with response to the previous question.

On question 5, "Are any special precautions taken, such as covering the tank and field with hay or manure, or other measures?", the response was, "yes", in 14 cases, "no", in 18 cases, with 5 not responding. In 4 of the affirmative replies, specific precautions were indicated as: cover systems with 8 to 10 inches manure (50 inches to 55 inches frost zone); bank system with 3 to 4 feet of dirt (50 inches to 55 inches frost zone); cover tank when used only in summer (40 inches to 45 inches frost zone); and, cover outlet, if to open ditch 20 inches to 25 inches frost zone).

Venting of absorption systems was indicated as uncommon in northern areas. Of 6 plumbers responding to inquiry on possible difference in operation of vented and unvented systems, with respect to freezing, 4 indicated that vented systems freeze, freeze more readily, or vents froze shut; and 2, that there was no difference.

The use of dosing siphons was also indicated as uncommon, about 90 per cent of the respondents stating that they are not used.

Summary

1. From comments in the literature concerning freezing aspects in particular states or areas, and from a review of the recommendations of eleven northern states on small septic

tank ground absorption systems, it appears that the freeze-up of a household system which has been installed with care, on the basis of the usual design recommendations of the states, is a rare occurrence. Only one of the colder border states recommends depths approaching the frost line, and one other recommends straw cover where subject to extreme frost.

2. From a review of several case histories it appears that difficulties are associated with failure to observe usual design recommendations, or to protect construction in freezing weather. Unprotected sewer lines under driveways appear to be particularly weak points.

3. Investigation of tanks in some of the more northerly sections of Canada by the Ontario Agricultural College led to the conclusion that no trouble ensues from tanks 12 inches below ground and disposal tile 18 to 24 inches under ground, if kept in continual use, and if no part of the system is under a hard-packed roadway.

4. Investigation of recent country school system freeze-ups revealed unusual conditions, such as no heat added to the water and longer periods of idleness both daily and weekly, as compared with household systems. During the school freeze-ups there were no known reports of household freeze-ups.

5. A poll of northern plumbers indicated small incidence of freezing in shallow systems.

6. It appears from the data at hand that a carefully constructed shallow household system, with gravel packed tile lines, and insulation of pipes under driveways, or other surfaces usually cleared of snow, will rarely freeze if kept in continuous operation.

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APPENDICES

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APPENDIX A

REVIEW OF LITERATURE

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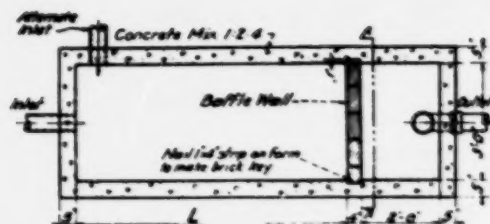
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 Watson, J. D. (55) (235)
 Watson, W. (604)
 Weaver, D. S. (176)
 Weber, E. (401)
 Weicker, G. (554)
 Weickert, O. (272)
 Welborn, M. C. (104)
 Welch, E. G. (177) (370)
 Weston, A. D. (444) (475) (486) (541)
 Whipple, G. C. (198)

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Wood, I. E. (253) (274) (275)
(276) (277) (301) (337)

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Wooley, J. C. (302)
Wright, F. B. (524)

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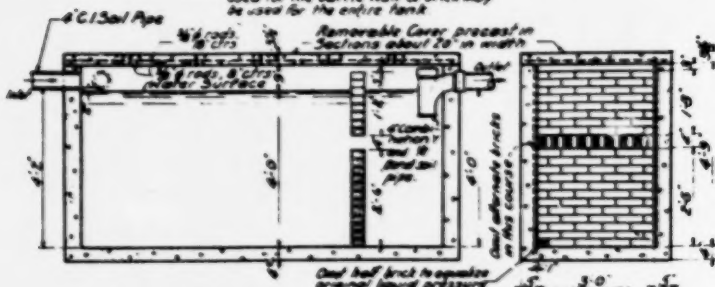
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Young, H. J. (361)



New Mexico State Health Dept.
Recommended Septic Tank

PLAN - COVER REMOVED

Note: Where preferred concrete may be used for the baffle wall or brick may be used for the entire tank.

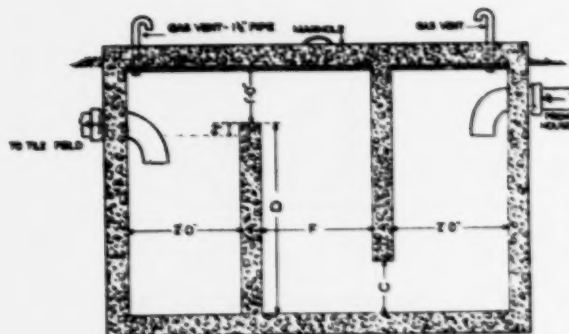


SECTIONAL VIEW OF SEPTIC TANK

SECTION A-A

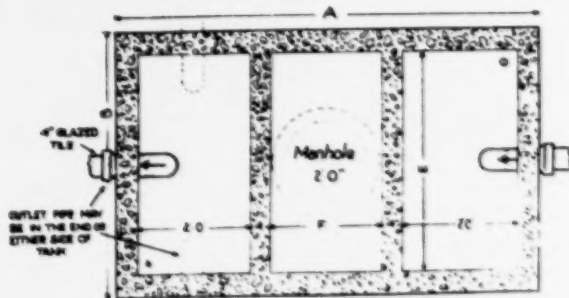
TABLE OF DIMENSIONS & QUANTITIES

No. of Length	Length of Inlet	Length of Outlet	Length of Baffle	Length of Tank	Length of Inlet	Length of Outlet	Length of Baffle	Length of Tank	Length of Inlet	Length of Outlet	Length of Baffle	Length of Tank
1-10	7'-0"	12'-0"	2'-0"	24'-0"	2'-0"	2'-0"	2'-0"	24'-0"	2'-0"	2'-0"	2'-0"	24'-0"
1-20	12'-0"	18'-0"	2'-0"	30'-0"	2'-0"	2'-0"	2'-0"	30'-0"	2'-0"	2'-0"	2'-0"	30'-0"
1-30	18'-0"	24'-0"	2'-0"	36'-0"	2'-0"	2'-0"	2'-0"	36'-0"	2'-0"	2'-0"	2'-0"	36'-0"
1-40	24'-0"	30'-0"	2'-0"	42'-0"	2'-0"	2'-0"	2'-0"	42'-0"	2'-0"	2'-0"	2'-0"	42'-0"
1-50	30'-0"	36'-0"	2'-0"	48'-0"	2'-0"	2'-0"	2'-0"	48'-0"	2'-0"	2'-0"	2'-0"	48'-0"

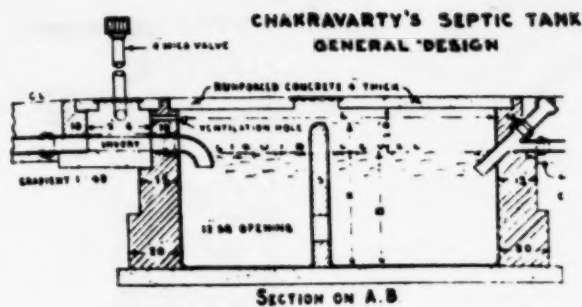


VERTICAL SECTION

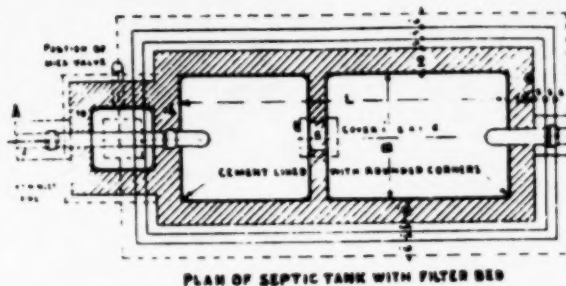
Kentucky State Health Dept.
Recommended Septic Tank



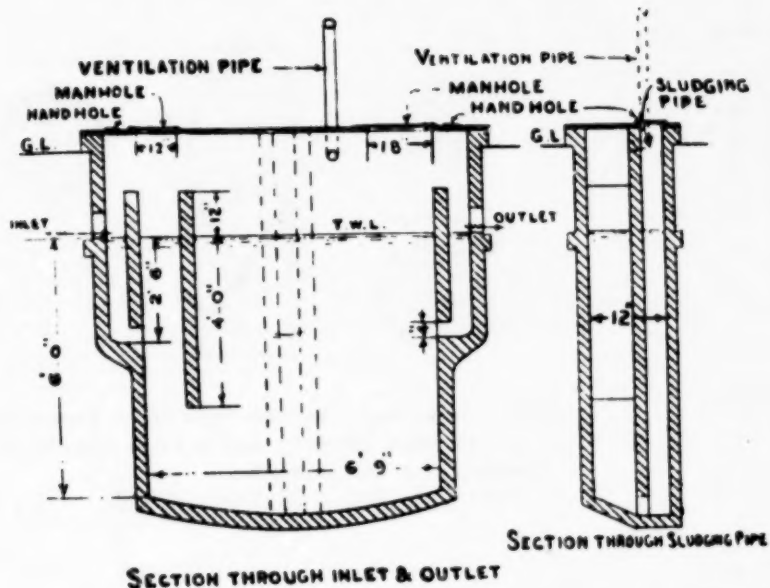
No. of Persons Served	DIMENSIONS							
	A	B	C	D	E	F	G	H
1-10	7	6	4	10	1	0	3	4
1-20	11	8	5	0	1	0	4	0
21-40	13	10	6	2	1	3	4	6
41-60	16	0	7	4	1	3	5	0



NO. OF PERSONS	L.	B.	D.	Capacity (Gallons)	Length of Inlet Pipe
10	5' 0"	3' 0"	3' 0"	37.00	2.75
20	7' 0"	3' 0"	3' 0"	61.00	2.75
30	11' 0"	3' 0"	3' 0"	130.75	2.75
40	14' 0"	3' 0"	3' 0"	188.00	2.75
50	16' 0"	3' 0"	3' 0"	271.75	2.75
60	17' 0"	3' 0"	3' 0"	330.00	2.75
70	18' 0"	3' 0"	3' 0"	388.00	2.75
80	19' 0"	3' 0"	3' 0"	446.00	2.75
90	20' 0"	3' 0"	3' 0"	504.00	2.75
100	21' 0"	3' 0"	3' 0"	562.00	2.75
120	24' 0"	3' 0"	3' 0"	688.00	2.75
140	27' 0"	3' 0"	3' 0"	814.00	2.75
160	30' 0"	3' 0"	3' 0"	940.00	2.75



Chakravarty's Septic Tank -
Used in India
(from: J. Instr. Engrs.,
42:139(1938))



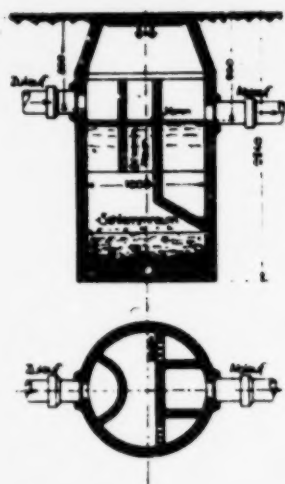
Tank for 20 persons as proposed by Temple. To be 1 ft.
3 in. wide if likely to be left alone indefinitely.
(from: J. Instr. Engrs., 42:139(1938))



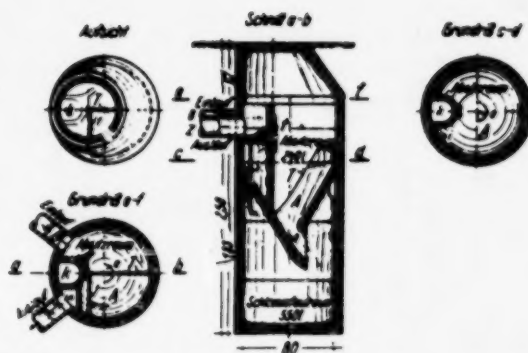
Treatment plant with pit built from concrete rings
(from: Ges. Ing., 52:943(1927))



A type of Fresh-water clarification tank
(from: Tech. Gemeindbl., 30:163 (1927/28))



A type of fresh water clarification tank with a slotted crest to second chamber
(from: Tech. Gemeindbl., 30:163(1927/28))



ETA - household septic tank with separate flow through chamber and sludge digestion chamber for 20 persons.
(from: Ges. Ing., 52:942 (1927))

APPENDIX B

SURVEY OF CONTROLS AND PRACTICES IN SOME LOCAL HEALTH UNITS

FEDERAL SECURITY AGENCY
U. S. PUBLIC HEALTH SERVICE
SANITARY ENGINEERING DIVISION

(Sample Circular Letter)

TO: ALL LOCAL HEALTH DEPARTMENTS

SUBJECT: HHFA - USPHS HOUSEHOLD SEWAGE DISPOSAL PROJECT

The U. S. Public Health Service is conducting a basic study of household septic tank sewage disposal systems sponsored by the Housing and Home Finance Agency for the purpose of determining design recommendations for the guidance of that Agency in connection with government involved housing, such as F.H.A. loan properties and properties involved in the veterans housing program, in unsewered areas.

The project, which got under way last year, includes a program of research on septic tanks and soil absorption system characteristics at the Cincinnati Laboratory, supplemented by examination of individual systems in operation in several localities over the country.

Due to the expense and time involved in field examinations, it will not be possible to reach each section by this means. In order to fill the need for a broad basis of appraisal and to take into account practices and experiences in all sections of the country, the Public Health Service, with the approval of your State Department of Health, is inviting the County and Municipal units to contribute through response to the attached questionnaire.

We know, through contacts with the State Health Departments, and through a review of some 600 sources of information on this subject from all over the world, that considerable confusion exists as to what the solution is of the many problems in this field. This condition exists due to a lack of basic facts. This project is an attempt to develop the facts, and the results will be made available, upon completion of the study, to all interested, through government publications. The questionnaire goes into the detailed program of the local health unit, in connection with which we wish to explain that its purpose is merely to develop facts on local practices and control as they exist and there is no intention of utilizing the information to criticize any individual program.

Your cooperation in assisting through response to the attached questionnaire will be deeply appreciated. In cases where space may not be sufficient for the development of items of particular significance in your experience feel free to expand your response on a separate sheet.

For the Officer in Charge.

Very truly yours,

U. S. PUBLIC HEALTH SERVICE Budget Bureau No. 68-4805
ENVIRONMENTAL HEALTH CENTER Approval Expires
EAST THIRD & KILGOUR STREETS June 30, 1948
Cincinnati 2, Ohio

H.H.F.A. - U.S.P.H.S. Household Sewage Disposal Project

1. Is there regulatory control over household septic tank sewage disposal systems in your City _____ County _____ City-County _____ Local District _____ State District _____ area? _____
Yes No
If yes, is control in all or part of your area? _____. If only in part, what part? _____.
2. Name of department exercising control _____
Year control started _____. (Please attach copy of code, ordinance or other authority).
3. Does department issue local design requirements for such systems? _____
Utilize State Health Department Recommendations? _____
Yes No
(Please attach copy of local requirements or recommendations).
4. How many household septic tank disposal systems are there in the area? _____
How many were installed under the control above mentioned? _____.
Check whether figures are estimate _____ or, from records _____.
5. Does the control agency:
 - a. Require installation permits? _____ (Please attach sample permit).
Yes No
 - b. Require installation by skilled tradesmen or services? _____
Yes No
If so, what type of tradesmen or services? _____

 - c. Maintain a record of individual installations? _____
Yes No
(Please attach sample card).
 - d. Maintain a record of complaints? _____
Yes No
 - e. Make preliminary inspection of site? _____ (in _____ % of cases), _____.
Yes No
 - f. Make percolation tests? _____ (in _____ % of cases), _____.
Yes No

- (Please attach copies if available.)

- a. Nature of complaints

- b. Causes of difficulties

8. Are septic tank cleaning services regulated in any way? _____

- 215 -

9. What difficulties, if any, are experienced with septic tank cleaning services in your locality, such as: Exorbitant charges, misrepresentation, insanitary disposal of cleanings, court cases, etc. _____

 (Please attach available documentary material)

10. What is local cost of cleaning septic tanks? (Please add the gallon capacity of tanks or truck loads involved in cost units, give any sliding scale schedules, cost differentials based on compartments, and details of any contractual services).

\$ _____ per _____. Explain. _____

11. Please insert any available local costs for the following:

a. Septic Tanks (300 to 1,500 gals. liquid cap.)

<u>Liquid cap. gals.</u>	<u>Kind of const'n mat'l</u>	<u>Cost Delivered</u>	<u>Cost Installed</u>	<u>Cost to Install</u>
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

b. Tile field, per foot of length \$ _____.

c. A complete installation \$ _____, includes what?

12. If you cannot furnish cost figures (items 10 and 11) kindly list local sources from which these might be obtained:

13. Please outline any control, design, installation, servicing and maintenance practices which have been particularly successful in your locality:

14. Respondent to questionnaire

Name, title _____

Agency _____

Date _____

APPENDIX C

STUDY OF EXPERIMENTALLY OPERATED SEPTIC TANKS

ANALYTICAL PROCEDURES

A. Solids

In the routine chemical examination of sewage and effluent, the procedures recommended by Standard Methods for the Examination of Wastes and Sewage, Ninth Edition, were followed with minor modifications.

Total solids, total volatile, and fixed solids were determined exactly as recommended, that is, 100 milliliters of sample was evaporated on a steam bath in a tared, ignited dish, dried at 103° centigrade for 1 hour and then weighed.

The procedure for total suspended solids, volatile and fixed suspended solids was adhered to in all but the preparation of the Gooch crucibles. The method developed in this laboratory has yielded mats of consistent weight and presumably consistent porosity. The asbestos cream was prepared by suspending 3.5 grams of acid-washed, medium fibre asbestos in about 300 to 400 milliliters of distilled water and mixing in a Waring Blendor for 30 seconds. The volume was then brought up to 1000 milliliters with distilled water. The resultant suspension was uniform and settled at an even rate. A suitable mat was obtained by pouring 12 milliliters of the well-shaken asbestos suspension on to the crucible. After allowing the suspension to settle for a few seconds, gentle suction was applied and finally full suction. The crucibles were dried at 103° centigrade and then ignited at 600° to 650° centigrade for 20 minutes, cooled and weighed. Ignition of the total suspended solids for the determination of volatile suspended solids were carried out at the above temperature and time. A 100 milliliters sample of raw sewage and effluent was used. Analysis of sludge necessitated using a smaller aliquot.

Values for the dissolved solids were obtained by differences between total solids and suspended solids.

B. Total Sulfides

The colorimetric method outlined in Standard Methods for the determination of total sulfides was followed with some modification.

Sampling.

Sample for total sulfides was obtained by submerging an open 250 milliliter glass stoppered bottle 10 inches below the liquid level and completely filling with sample excluding any air bubbles. Determinations of total sulfides were made within a half hour after collection. Tests performed on effluent samples, before and after storage, indicated that samples may be stored in glass stoppered bottles devoid of air bubbles in the refrigerator for two hours without any noticeable change in sulfide concentration.

Standardization of Methylene Blue Solution.

(This is not given in Standard Methods).

Prepare a solution of 1.00 grams methylene blue per liter. Standardize against sodium sulfide.

1. Completely fill a 4 liter bottle with distilled water.
2. Add a washed crystal of sodium sulfide weighing 100 to 200 milligrams.
3. Stopper the bottle with the exclusion of air and mix thoroughly.
4. Pipette 20 milliliters N/40 iodine solution into a 500 milliliter volumetric flask.

5. Siphon into the volumetric flask sulfide solution from the bottom of the 4 liter bottle to fill to the mark.

6. Transfer to a beaker, add 1 milliliter H_2SO_4 and titrate excess iodine solution with N/40, thiosulfate.

7. The concentration of sulfide ion in p.p.m. is obtained by multiplying the net volume of iodine used by 0.835.

8. This solution of known sulfide concentration is then analyzed by the following method to standardize the methylene blue solution.

Method for Total Sulfides.

(See Standard Methods for Preparation of Reagents).

1. 7.5 milliliters sample (or less) is added to each of two 100 milliliters Nessler tubes.

2. Add 0.5 milliliters amine reagent to one, 0.5 milliliters dilute sulfuric acid to the other.

3. Add 2 drops ferric chloride solution to both, mix.

4. Blue color develops in 1 to 5 minutes in presence of sulfides. A pink color develops in absence of sulfide.

5. Add 1.0 milliliters diammonium phosphate to both, slowly and with mixing.

6. Dilute with distilled water to 100 milliliter mark.

7. Titrate with standard methylene blue solution to match blue color.

In this laboratory a semi-micro burette was used for titration instead of a pipette as recommended in Standard Methods. Also, for greater accuracy low form 100 milliliters. Nessler tubes were used for matching colors instead of the recommended test tubes.

C. Determination of Grease

One method outlined in Standard Methods, ninth edition, was followed. In many samples stable emulsions have formed that were hard to separate. These emulsions were separated by filtration through filter paper which had been moistened with petroleum ether.

D. Determination of Organic Carbon in Soils

The procedure for the determination of organic carbon in soils was that proposed by Prof. A. L. Prince, Soils Department, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey. The method consisted of taking an aliquot, 0.5 to 20 grams of the soil under test, adding 10 milliliters concentration of H_2SO_4 , 15 milliliters of 0.500 N. potassium dichromate solution, boiling moderately with a funnel condenser for 5 minutes, cooling, diluting with 250 milliliters distilled water and titrating with standard ferrous ammonium sulfate solution, using 3 drops of ortho-phenanthroline ferrous complex indicator.

E. Determination of Chlorides

For the determination of Chlorides, the Volhard method as outlined in Standard Methods was used.

F. Determination of pH of Soils

For the determination of pH of soils, 25 grams of sample was added to 25 milliliters of distilled water, stirred and allowed to stand for 30 minutes. The pH of the stirred soil suspension, not the supernatant, was then obtained with a MacPeth type pH meter. The reading should be made rapidly because of drift in some samples particularly those containing calcium carbonate.

EXPERIMENTALLY OPERATED SEPTIC TANKS

TABLE 79.--Scum Volume in Cubic Feet

Tank	June 24, 1947	July 1	July 8	July 15	July 22	July 29	Aug. 5	Aug. 12	Aug. 19
1									
2	0.70	1.16	1.40	1.40	0.98	0.56	0.56	0.51	0.23
3		0.5+	0.2+	0.8	1.31	2.23	2.04	2.99	2.48
3a ¹				0.02	1.29	2.17	1.61	2.65	2.24
3b ¹		0.5	0.02	0.06	0.02	0.06	0.43	0.34	0.24
4	0.26+	0.47+	1.19	1.56	1.74	1.13	1.10	2.19	3.04
4a ¹		tr	0.87	1.15	1.14	0.93	0.72	1.39	1.69
4b ¹	0.13	0.18	0.30	0.38	0.58	0.08	0.21	0.59	1.01
4c ¹	0.13	0.27	0.01	0.02	0.01	0.11	0.16	0.19	0.27
4d ¹	tr	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.07
5	0.94	1.27	2.39	1.27	0.05	0.37	0.50	0.42	0.37
6	1.57	1.57	1.21	1.44	0.49	0.31	0.49	0.54	0.27
7	1.48	1.42	1.28	1.63	0.12	0.47	0.47	0.59	0.18
8	0.61	1.22	1.25	1.07	0.91	0.61	0.61	0.91	0.61

¹ Sub-letter is used to indicate a particular compartment or unit of a compartmented or series type of installation: i.e., "a" is first compartment; "b", the second compartment; "c", the third compartment, etc.

TABLE 79.--Scum Volume in Cubic Feet (cont'd)

Tanks	Aug. 27	Sept. 3	Sept. 10	Sept. 17	Oct. 2	Oct. 10	Jan. 19 1948	Jan. 26	Feb. 2	Feb. 9	Feb. 16	Feb. 24
1							0.78	1.02	1.08	0.72	0.90	0.54
2	0.05						0.14	0.23	0.09	0.19	0.09	0.09
3	2.13	2.49	2.02	0.60			0.33	0.43	0.56	1.20	0.37	0.11
3a	2.11	2.47	1.96	0.17			0.22	0.39	0.50	1.16	0.28	0.09
3b	0.02	0.02	0.06	0.43			0.11	0.04	0.06	0.04	0.09	0.02
4	1.80	1.82	1.73	0.73			0.40	0.80	0.91	1.04	0.77	0.84
4a	0.98	1.10	1.40	0.54			0.20	0.38	0.59	0.63	0.43	0.51
4b	0.81	0.70	0.33	0.19			0.20	0.26	0.26	0.37	0.30	0.27
4c	0.01	0.01					tr	0.15	0.05	0.03	0.03	0.04
4d	tr	0.01					tr	0.01	0.01	0.01	0.01	0.02
5	0.05						0.16	0.18	0.11	0.16	0.26	0.16
6	0.05						0.09	0.13	0.13	0.13	0.09	
7	0.06			0.18			0.06	0.06	0.18	0.89	0.06	0.12
8							0.73	0.13	0.13	0.20	0.33	0.13
9	0.06	0.30	0.71	0.59			0.18	3.40	0.29	0.30	0.59	0.24
12	0.06						tr	0.01	0.01	0.01	0.01	0.01
13	0.06		0.24				tr	0.02	0.02	0.02	0.02	0.02
13a							tr	0.01	0.01	0.01	0.01	0.01
13b							tr	0.01	0.01	0.01	0.01	0.01
14							0	0.08	0.07	0.08	0.07	0.08
14a							0	0.03	0.03	0.03	0.03	0.03
14b							0	0.03	0.02	0.03	0.02	0.03
14c							0	0.02	0.02	0.02	0.02	0.02

TABLE 79.--Scum Volume in Cubic Feet (cont'd)

Tank	Mar. 2	Mar. 15	Mar. 22	Mar. 29	Mar. 30	Apr. 19	Apr. 26	May 3	May 17	May 24	June 1	June 7	June 28
1	0.72	0.54	0.18	0	0	0	0	0	0	tr	0	tr	0
2	tr	tr	0.02	0	0	0	0	0	0	0	0	--	--
3	0.11	0.06	0.07	2.82	0.02	0	0	0	tr	tr	0	tr	0
3a	0.09	0.06	0.06	2.82	0.02	0	0	0	tr	tr	0	tr	0
3b	0.02	0	0.01	0	0	0	0	0	tr	tr	0	tr	0
4	0.26	0.20	0.20	0.14	0.05	0	0	0	tr	tr	0	tr	0
4a	0.24	0.19	0.19	0.14	0.05	0	0	0	tr	tr	0	tr	0
4b	0.01	0.01	0.01	0	0	0	0	0	tr	tr	0	tr	0
4c	0.01	tr	0	0	0	0	0	0	tr	tr	0	tr	0
4d	tr	tr	0	0	0	0	0	0	tr	tr	0	tr	0
5	0.05	0.05	0.05	0	0	0	0	0	tr	0	0	0	0
6	0.09	0.04	0.04	0	0	0	0	0	tr	0	0	0	0
7	0.06	0	0.03	0	0	0	0.18	0	tr	0	tr	0	0
8	0.03	tr	0	0	0	0	0	0	0	0	0	tr	0
9	0.24	0.06	0.30	0	0.59	0	0.59	0.59	0	0	0	--	--
12	0	0	0	0	0.03	0.01	0.02	0	0.33	0.69	0.59	0.02	0.58
13	0.03	0	0	0	0	0.01	0.03	0.08	--	tr	0.55+	0.03	0
13a	0.01	0	0	0	0	0.01	0.03	0.03	--	tr	tr	0.03	0
13b	0.02	0	0	0	0	0	0	0.05	--	tr	0.55	0	0
14	0.02	0	0	0	0.10	0.85	4.47	3.59	3.24	1.37	tr	tr	0
14a	0.01	0	0	0	0.10	0.85	0	0	0	0	0	0	0
14b	0.01	0	0	0	0	0	2.08	2.36	2.52	1.18	tr	tr	0
14c	tr	0	0	0	0	0	2.39	1.23	0.72	0.19	tr	tr	0
15									tr		0	0	0
16									0		0	tr	0
17									0		0	tr	0
18									0.18		0	tr	0

EXPERIMENTALLY OPERATED SEPTIC TANKS

TABLE 80.--Sludge Volumes in Cubic Feet

Tank	June 24, 1947	July 1	July 8	July 15	July 22	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 27	Sept. 3	Sept. 10	Sept. 17
1	14.98	15.88	9.39		16.16	15.80	14.80	17.80	16.00	16.21	16.42	17.31	19.50
2	1.99	1.74	1.44		1.44	1.93	2.02	2.10	1.87	2.54	2.59	3.09	2.47
3	2.36+	3.85+	5.16		4.00	4.99	3.89	4.04	4.18	4.64	3.98	2.13	8.64
3a ¹	2.36	3.85	4.54		3.38	4.00	3.27	3.42	3.32	3.93	3.01	1.05	5.35
3b ¹	0.71	0.62	0.62		0.62	0.99	0.62	0.62	0.86	0.71	0.97	1.08	3.29
4	5.19	5.73	4.37		3.40	4.88	5.73	4.19	3.20	4.77	4.33	6.47	7.49
4a ¹	1.78	2.70	2.38		2.06	3.57	4.52	2.75	1.73	2.81	1.89	2.97	3.26
4b ¹	0.88	0.65	0.74		0.32	0.38	0.51	0.34	0.50	0.49	0.72	1.13	1.65
4c ¹	1.04	1.26	0.32		0.32	0.32	0.32	0.54	0.69	0.75	0.70	1.14	1.30
4d ¹	1.49	1.12	0.93		0.70	0.61	0.38	0.56	0.28	0.72	1.02	1.23	1.28
5	3.10	3.08	1.54		3.76	1.88	2.88	3.71	3.74	4.03	4.03	4.98	5.15
6	1.48	1.79	1.35		2.20	1.93	1.62	2.34	2.03	2.83	2.26	3.43	3.34
7	2.88	1.96	1.72		3.22	2.52	2.67	3.10	3.01	3.80	3.49	6.05	5.12
8	0.67	0.34	0.36		0.91	1.46	1.58	1.40	2.16	1.86	2.31	3.04	3.27
9										1.72	1.80	2.21	4.05
10										1.72	1.72	1.72	1.72
11										1.72	1.72	1.72	1.72

Sub-letter is used to indicate a particular compartment or unit of a compartmented or series type of installations; i.e., "a" is first compartment; "b", the second compartment; "c", the third compartment, etc.

TABLE 80.--Sludge Volumes in Cubic Feet (cont'd)

TANK	Oct. 2	Oct. 10	Oct. 16	Oct. 30	Nov. 6	Nov. 24	Dec. 1	Dec. 8	Dec. 15	Dec. 22	Dec. 29	Jan. 5 1948
1	20.0	34.1	41.8	34.5	33.6	47.7	47.0	52.7	48.0	56.0	55.92	56.10
2	7.35	19.57	17.78	16.60	18.90	28.0	26.5	25.7	25.7	24.0	21.12	22.11
3	11.22	19.11	19.62	21.66	20.61	20.23	29.8	29.9	28.93	31.60	30.38	27.29
3a	8.17	15.45	16.50	16.22	14.53	13.58	21.2	21.1	20.35	19.90	20.96	18.43
3b	3.05	3.66	3.12	5.44	6.08	6.65	8.6	8.8	8.58	11.70	9.42	8.86
4	9.94	14.79		21.87	23.97	32.87	33.23	33.65	32.68	42.42	34.07	31.93
4a	5.03	6.91		9.48	10.31	13.30	14.08	13.80	14.08	13.60	13.59	12.87
4b	1.42	4.97		8.16	8.99	10.60	12.27	11.53	10.84	10.86	12.49	10.41
4c	1.94	1.62		2.65	3.08	5.30	5.06	6.00	5.65	5.83	5.80	6.00
4d	1.55	1.39		1.58	1.59	3.67	1.82	2.32	2.11	2.16	2.19	2.65
5	8.05	20.3	24.3	20.5	21.5	26.0	24.9	32.7	31.0	33.1	29.52	28.30
6	4.87	17.4	22.5	15.98	18.44	29.0	25.4	25.4	23.7	25.5	25.91	27.48
7	6.29	16.0	18.09	15.53	29.35	26.9	28.3	28.7	27.2	26.7	26.15	26.98
8	4.17	12.91	15.50	11.23	12.43	21.5	23.8	19.22	18.90	18.68	21.5	19.84
9	6.70	14.08		14.11	15.18	25.7	36.6	26.5	26.7	27.4	28.70	27.12
10				8.95								
11				7.81								
12								0.52	0.77	1.62		2.00
13								0.85	1.46	2.25	2.94	3.86
13a								0.59	1.15	1.64	2.17	3.04
13b								0.26	0.31	0.61	0.77	0.82
14D												

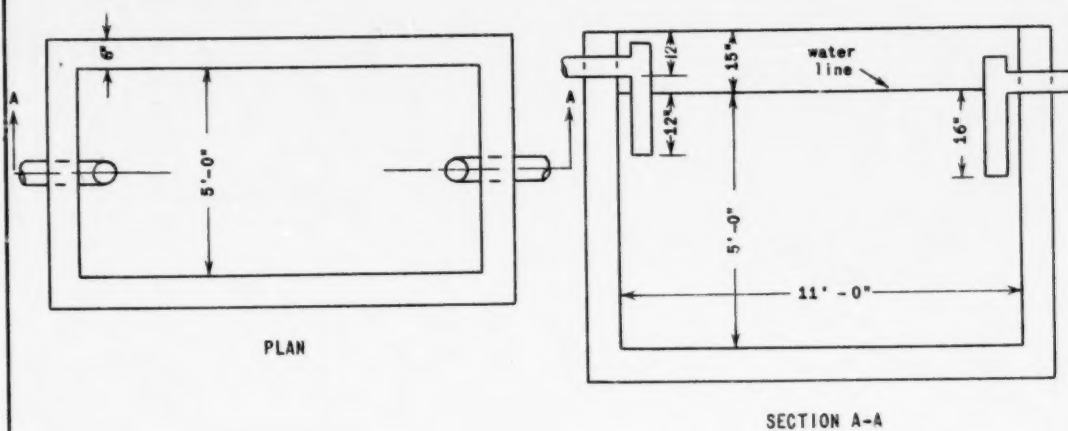
TABLE 80.--Sludge Volumes in Cubic Feet (cont'd)

Tank	Jan. 12	Jan. 19	Jan. 26	Feb. 2	Feb. 9	Feb. 16	Feb. 24	Mar. 2	Mar. 15	Mar. 22	Mar. 29	Mar. 30
1	56.7	57.0	57.2	59.1	57.2	59.6	161.1	101.7	94.0	95.8	86.1	93.1
2	23.1	29.3	21.6	21.3	21.5	21.4	18.75	17.94	23.08	20.58	18.8	24.4
3	34.83	32.65	30.6	31.65	33.3	29.01	31.07	29.30	31.96	31.06	28.37	33.09
3a	21.7	20.6	20.3	20.1	22.2	17.16	20.36	18.90	20.80	20.08	18.00	23.15
3b	13.13	12.05	10.3	11.55	11.1	11.85	10.71	10.40	11.16	10.98	10.37	9.94
4	35.60	38.88	32.16	33.88	34.36	34.38	34.29	33.74	42.73	37.13	36.53	39.13
4a	14.06	13.40	12.50	12.52	12.02	12.05	11.86	11.14	13.26	12.90	11.30	13.31
4b	11.00	12.04	10.20	10.86	11.76	10.44	11.12	10.97	11.82	10.95	11.70	13.14
4c	7.01	10.82	6.55	7.62	7.09	8.21	7.66	8.06	13.98	9.36	9.63	8.96
4d	3.53	2.62	2.91	2.88	3.49	3.68	3.65	3.57	3.67	3.92	3.90	3.72
5	31.7	29.6	28.3	36.1	29.5	27.74	31.33	27.83	31.38	27.46	29.7	30.5
6	24.9	23.6	32.8	23.4	25.0	21.08		23.77	25.24	22.62	21.5	27.8
7	28.2	27.4	25.3	27.5	28.0	25.62	26.33	25.28	27.40	25.62	25.8	29.3
8	20.70	19.77	18.87	18.79	17.27	18.55	16.78	13.63	16.21	20.91	15.20	18.38
9	29.0	26.8	25.9	30.4	28.1	24.98	30.67	30.5	29.41	35.41	25.4	32.1
10												
10												
12	2.78	3.15	3.61	4.41	4.74	5.27	7.63	7.86	7.09	7.03	7.09	9.92
13	5.16	5.44	4.72	5.67	6.09	6.33	9.20	10.57	10.82	9.27	11.03	14.60
13a	3.83	4.52	3.51	4.58	4.73	5.00	7.16	7.88	8.20	7.52	7.77	10.17
13b	1.33	0.92	1.21	1.09	1.36	1.33	2.04	2.69	2.62	1.75	3.26	4.43
14					2.85	2.72	6.12	4.81	5.90	6.17	6.65	10.73
14a					2.49	2.39	5.50	4.14	4.77	4.90	5.18	9.10
14b					0.25	0.17	0.50	0.57	1.01	1.19	1.37	1.52
14c					0.11	0.16	0.12	0.10	0.12	0.08	0.10	0.11

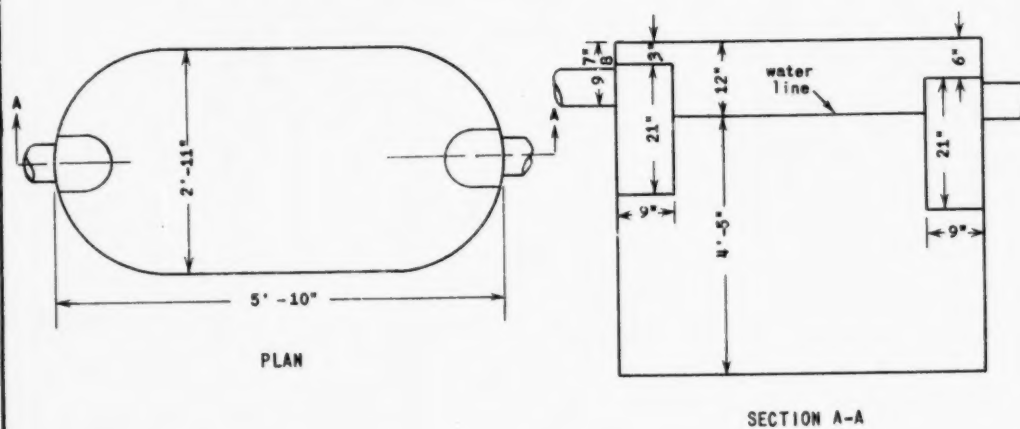
TABLE 80.--Sludge Volumes in Cubic Feet (cont'd)

Tank	Apr. 5	Apr. 12	Apr. 19	Apr. 26	May 3	May 10	May 17	May 24		June 7	June 28
1	93.6	111.7	101.0	100.4	96.4	94.4	106.8	88.5	93.2	90.6	90.5
2	24.2	25.3	25.0	23.6	22.76	20.5	11.5	11.85	14.3		13.57
3	31.55	33.88	34.77	34.36		36.18	36.43	33.30	37.04	34.3	36.56
3a	19.58	21.6	22.2	20.1	21.0	22.05	21.34	19.32	23.92	18.4	20.15
3b	11.97	12.28	12.57	14.26	20.2	14.13	15.09	13.98	13.12	15.9	16.41
4	41.85	39.78	39.21	42.29	41.95	39.74	42.18	40.38	40.37	41.11	42.64
4a	14.05	13.52	12.42	13.42	11.64	11.53	12.97	9.97	10.97	10.30	10.69
4b	13.86	12.21	12.28	12.22	12.16	11.59	13.08	12.47	11.41	11.73	13.83
4c	10.20	9.48	9.78	12.17	11.98	10.46	12.97	11.04	11.40	12.08	11.32
4d	3.74	4.57	4.73	4.48	6.17	6.16	6.91	6.90	6.59	7.00	6.80
5	32.97	32.1	34.2	31.0	31.64	31.60	32.85	29.8	28.1	31.8	29.05
6	27.18	26.1	27.9	29.67	24.43	24.5	24.3	23.8	23.4	22.4	21.14
7	29.23	32.2	27.9	31.2	29.18	29.2	29.6	28.5	26.8	28.7	28.3
8	16.75	22.2	16.30	17.04	15.18	19.84	11.63	12.1	11.8		12.5
9	31.24	30.9	31.4	34.75	33.42	30.65	31.6	36.6	32.0	29.2	31.9
10											
11											
12	10.02	7.98	8.70	9.01	10.98	9.10	7.99	6.71	5.59	6.29	5.13
13	14.70	13.50	12.06	13.14	12.55	12.68		11.63	10.54	9.85	10.13
13a	9.38	9.03	7.33	6.94	6.57	6.36		5.86	5.40	4.27	4.45
13b	5.32	4.47	4.73	6.20	5.98	6.32		5.77	5.14	5.58	5.68
14	11.81	9.94	6.64	6.14	5.18	5.04	3.69	5.10	6.61	4.56	3.17
14a	7.35	5.21	5.45	5.29	4.56	3.74	2.50	2.58	0.80	1.06	0.21
14b	2.98	1.61	0.71	0.73	0.36	1.09	0.53	1.55	3.38	1.78	1.61
14c	1.48	3.12	0.48	0.12	0.26	0.21	0.66	0.97	2.43	1.72	1.35

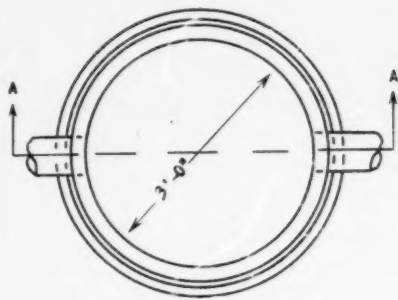
TANK 1 - JOINT COMMITTEE, LARGE
CONCRETE



TANK 2 - ROUNDED END
STEEL

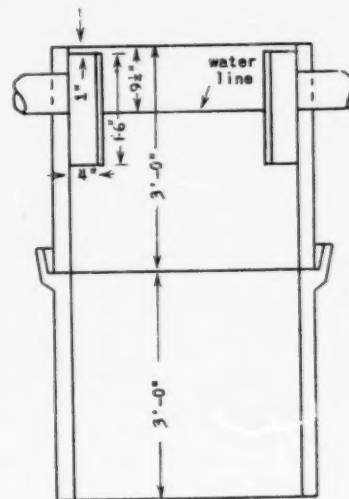


TANK 3 - TILE, LARGE
VITRIFIED TILE



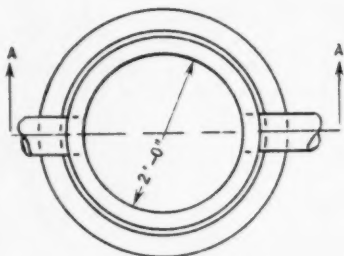
PLAN

NOTE: Two tile tanks connected
in series.



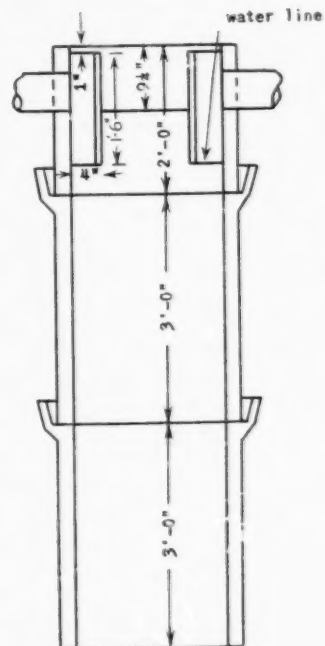
SECTION A-A

TANK 4 - TILE, SMALL
VITRIFIED TILE



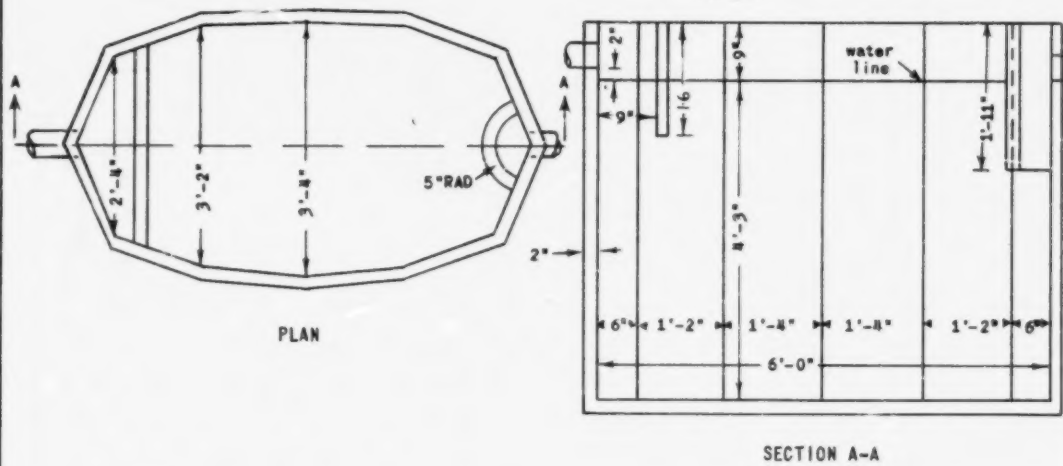
PLAN

NOTE: Four tile tanks connected
in series.

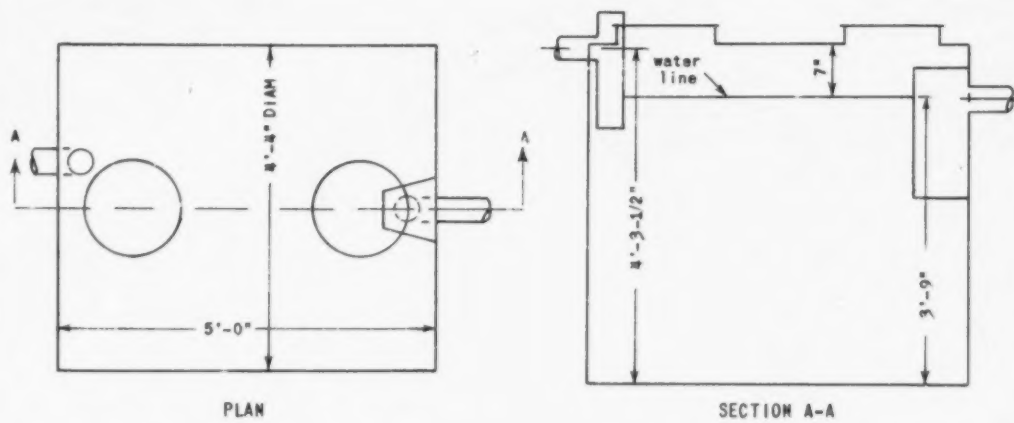


SECTION A-A

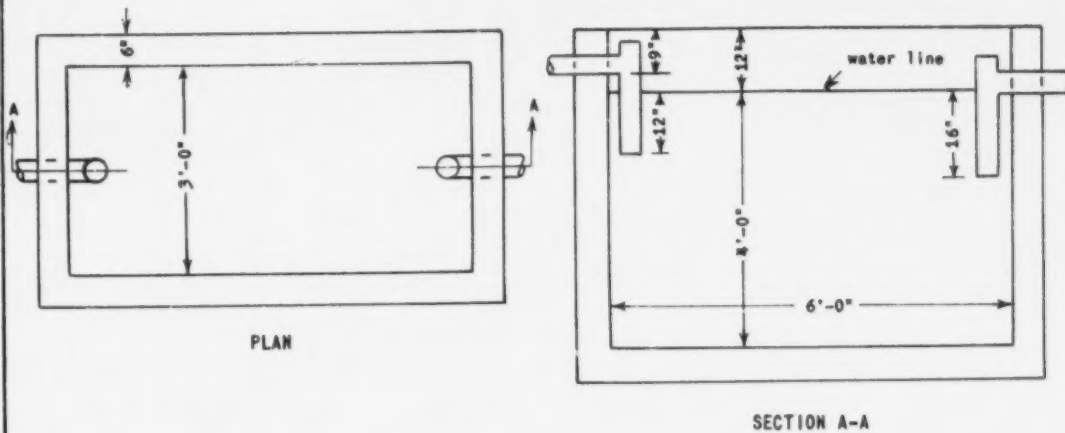
TANK 5 - OVAL SHAPED
CONCRETE



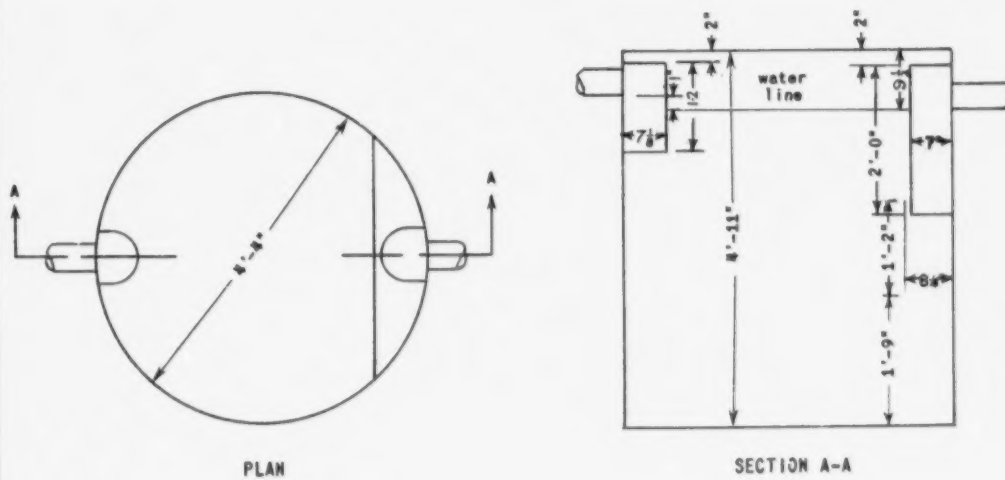
TANK 8 - HORIZONTAL CYLINDRICAL
STEEL



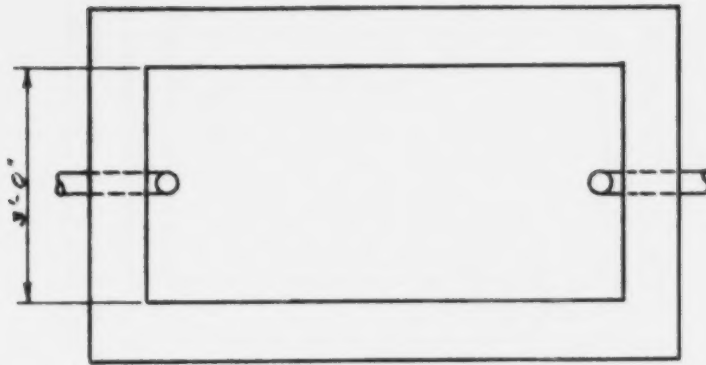
TANK 7 - JOINT COMMITTEE, SHALL
CONCRETE



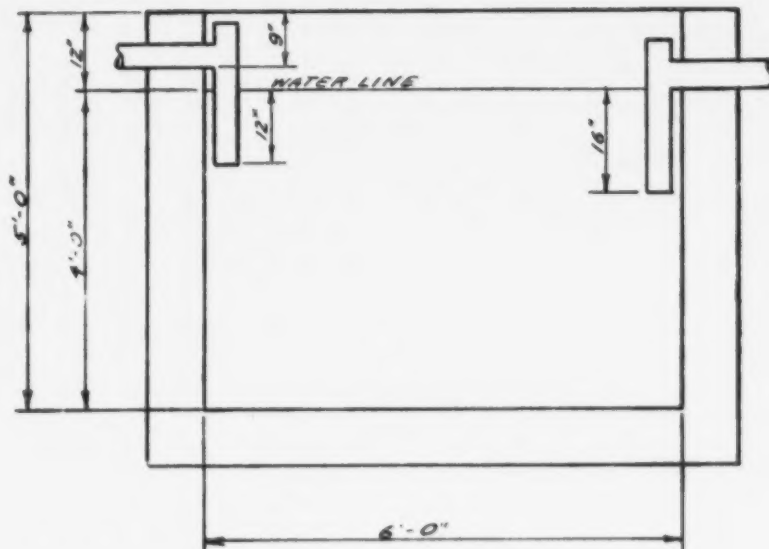
TANK 6 - VERTICAL CYLINDER
STEEL



TANK 9 - JT. COMM. - GARBAGE
 TANK 10 - JT. COMM. - CONTROL, WEIR
 TANK 15 - JT. COMM. - CONTROL, COMPARTMENTS

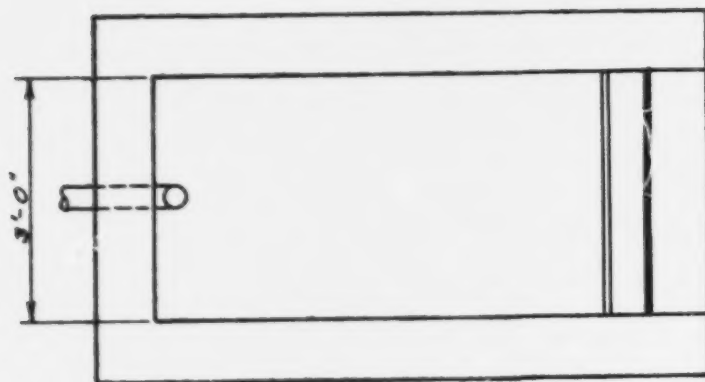


PLAN

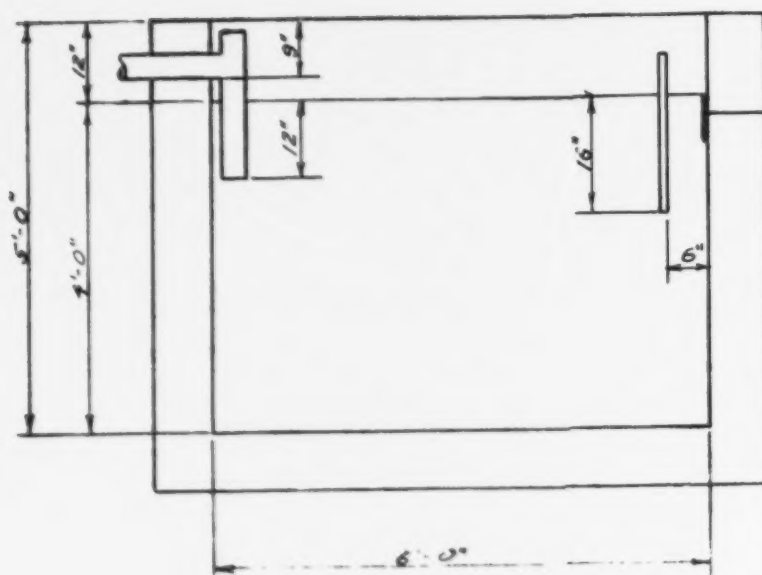


SECTION

TANK 11 - JT. COMM. - WEIR OUTLET



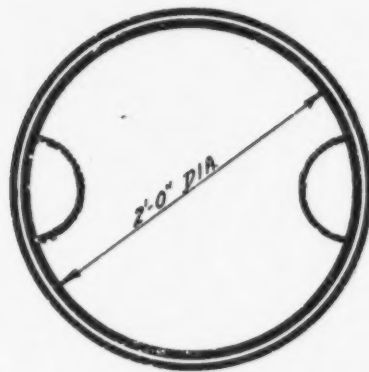
PLAN



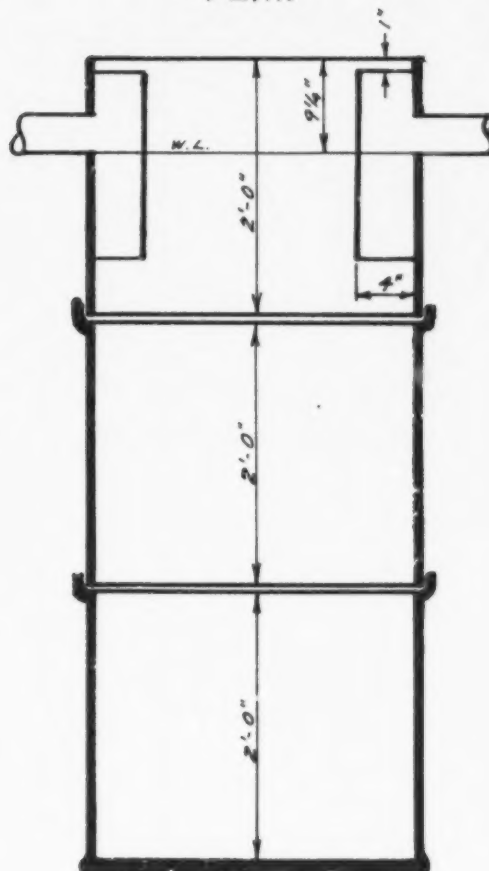
SECTION

TANK 12 - TILE, SMALL - SINGLE STACK

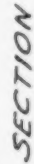
TANK 13 - TILE, SMALL - DOUBLE STACK, SERIES



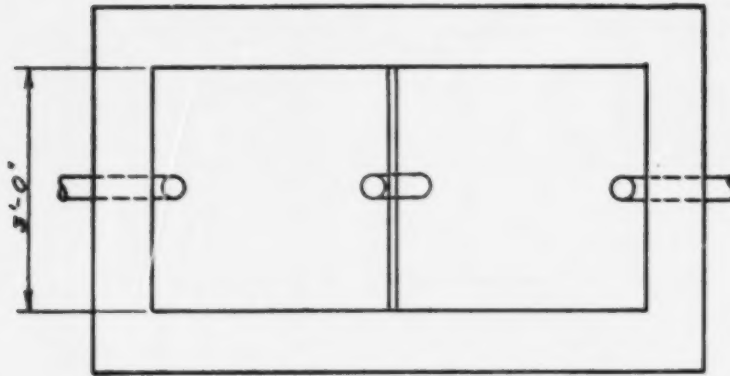
PLAN



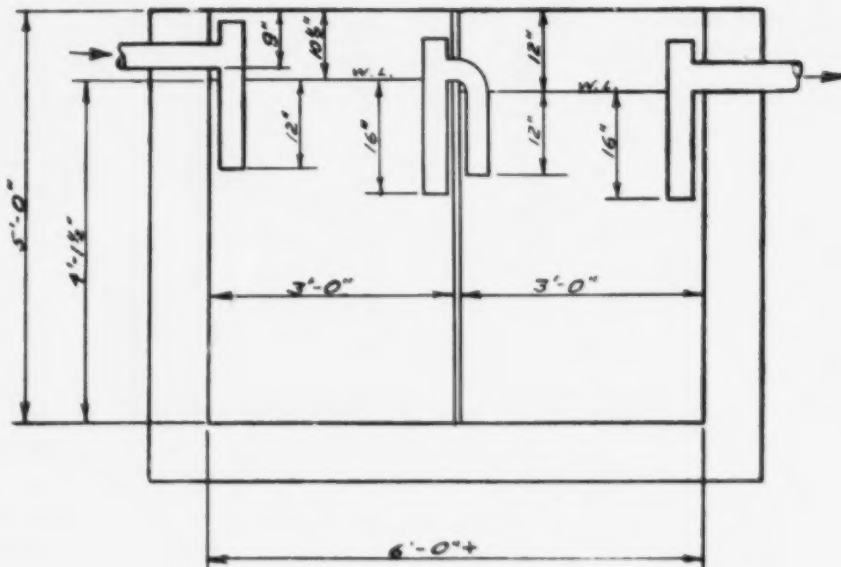
SECTION



TANK 16 - JT. COMM. - 2 COMPARTMENTS

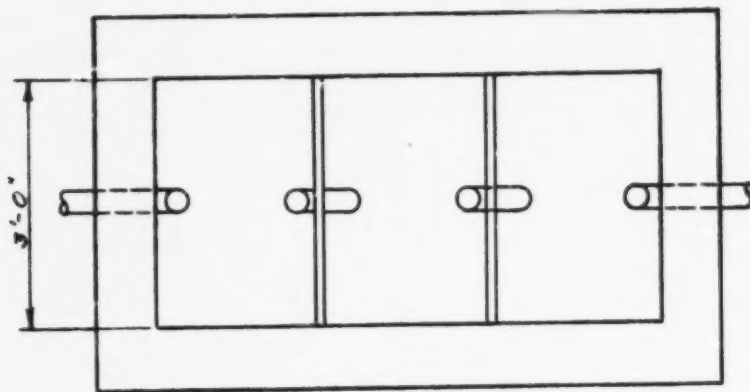


PLAN

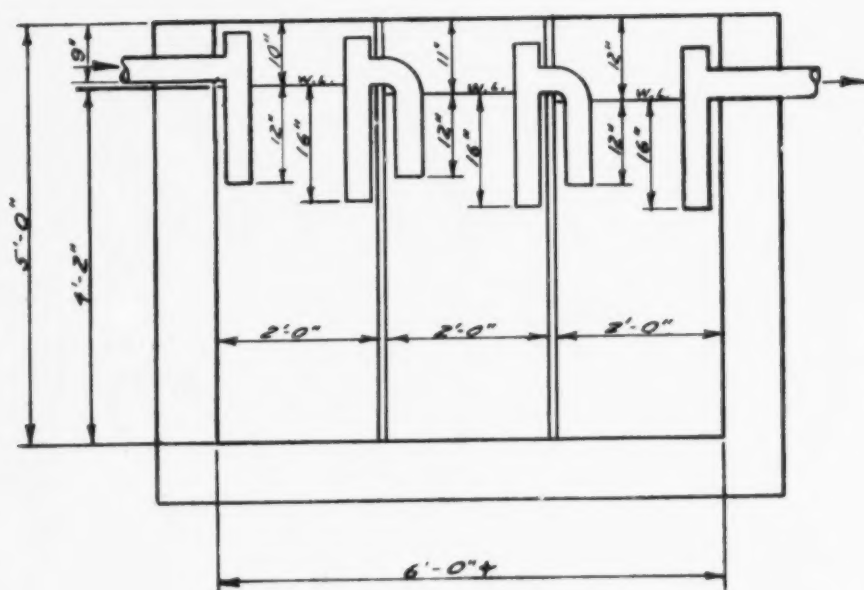


SECTION

TANK 17 - JT. COMM. - 3 COMPARTMENT

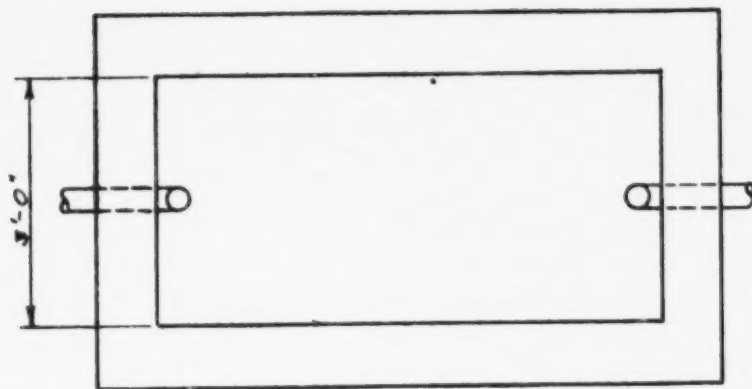


PLAN

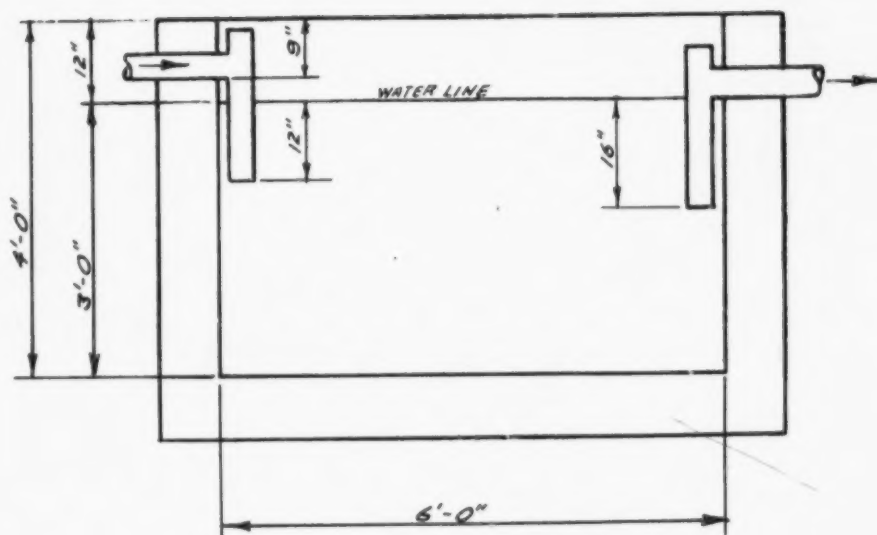


SECTION

TANK 18 - JT.COMM. - 3 FT. WATER DEPTH



PLAN



SECTION

APPENDIX D

STUDY OF SEPTIC TANKS IN FIELD, SLUDGE AND SCUM ACCUMULATION

STUDY OF HOUSEHOLD SEWAGE DISPOSAL SYSTEMS

To: Field Engineers
From: S. R. Weibel
Subject: Field Investigations - Preliminary Instructions

The Study of household sewage disposal systems is undertaken by the Service under a co-operative arrangement between the U. S. Public Health Service and the National Housing Agency wherein the Service will execute a program of study in accordance with project objectives set up by the National Housing Agency, the sponsoring agency. Under present arrangements sponsorship of the study by the National Housing Agency covers the period from December 16, 1946 to December 31, 1947.

The National Housing Agency has divided the project plan into three stages of investigation, the first two concerning problems for which results may be developed through a short period of study, and the third stage, topics of a more involved nature, requiring on the whole a longer period of time for completion. A Service report to the National Housing Agency on stages one and two is scheduled for June 30, 1947; on stage three, by December 31, 1947.

The problems outlined by the National Housing Agency are as follows:

Stage 1

1. Collection and analyses of existing data

A. Review existing publications and unpublished studies both domestic and foreign, regulations, and commercial brochures on the design, capacity, durability of construction materials and operating results of septic tanks and disposal systems and indicate such publications that offer information on acceptable principles to be followed.

B. Select representative installations of various types for sampling and gauging operations.

2. Investigate existing installations of different sizes, shapes, types, and materials, and determine efficiency of sedimentations, durability of materials, adequacy of sludge storage, and other basic characteristics.

3. Develop minimum standards of design for commercial septic tanks.

Stage 2

1. Conduct such short term research as may be possible and desirable to substantiate the objectives outlined in Stage 1 with particular reference to such items as efficiency of sedimentation, adequacy of sludge storage, capacity, size, shape, durability of materials and other comparable characteristics of commercial septic tanks.

Stage 3

It is appreciated that to be informative, certain observations must extend over considerable periods of time to furnish reliable information on septic tank in operations. Accordingly, under this heading are included such investigations as the following:

1. Locate, construct, or otherwise secure at properly selected field location and operate, under normal conditions, tanks of some flexibility for trials and pilot studies.
2. Locate, construct, or otherwise secure at properly selected field locations and operate subsurface systems on experimental basis, including experimental seepage test holes, trenches, tile lines, and complete subsurface installations.
3. Initiate sampling and gauging of several installations representative of current practices.
4. Conduct laboratory investigations on the soil-clogging characteristics of tank effluent.
5. Study the economic and general feasibility of constructing systems with sufficient sludge to require cleaning at only 10-or 20-year intervals.
6. Study the effect of extreme freezing conditions on the functioning of a properly designed and constructed subsurface disposal field and determine what modifications should be incorporated in accepted design practices for cold climates.
7. Study the effect of tree and shrubbery roots on disposal systems and the ability of roots to absorb significant portions of sewage effluent through all seasons of the year.
8. Determine the effect of residential garbage grinding on septic tanks operating and what modifications in design should be made to permit this service.
9. Test various distribution box installations as a basis for determining the most efficient design for these structures.
10. Investigate feasibility of changing the ratio of horizontal and vertical areas of septic tanks so as to permit a shorter detention period and increased sludge storage capacity.
11. Study the discharge of normal amounts of grease directly into a septic tank of adequate size and determine the effect of grease on septic action and on the efficiency of septic tank systems.
12. Determine the relation of Sodium and Calcium to the soil-clogging action of the effluent.
13. Investigate the relationship of (a) seepage, lateral or vertical (b) evaporation and (c) transpiration to the overall efficiency of a subsurface disposal systems.
14. Study and investigate new methods of disposal, particularly substitute methods for subsurface disposal.
15. Develop recommended minimum standards of design for septic tank systems.

In order to develop the facts as quickly as possible a study of installations in operation in the field will be carried out simultaneously with the research at Cincinnati. Present intentions are to start the field studies in three areas located in the north, south and central sections of the country. The development of additional studies in other areas is a likelihood depending on personnel circumstances and the experience gained in the initial study areas.

Efforts have been made, through contacts by members of the Cincinnati Station staff with the Service District offices and with the State Health Departments, to locate areas in the mid-continent states where circumstances are such that a field study of household sewage disposal systems can be carried out with maximum effectiveness. The factors of primary

significance in considering various areas are the existence of a large number of household disposal systems, an organized source of records on such systems, such as a county or local health department, the availability of local laboratory space, and, a high degree of interest and cooperativeness in such a study by state and local officials.

The selection of areas therefore envisages close cooperation with the state and, through it, the local health officials, an established policy of the Service. The field engineer is expected to maintain such relations and to conduct himself in conformity with the standards, customs and procedures of the department with which he is cooperating.

The object of the field investigation is to collect factual information on a number of household sewage disposal systems of various types in operation under normal circumstances. Some of the information sought in the field will supplement research being carried on at Cincinnati. Some factors, such as sludge and scum accumulation, and the status of an absorption field after a period of service, which cannot be developed experimentally in the short period of time available for the study, will depend almost completely on data obtained in the field for their development.

Report forms for the field investigations are being prepared. It is anticipated that these will not be available for field use for at least three weeks. Engineers assigned to field duty prior to the release of the official forms will be furnished temporary guidance material for the conduct of inspections in the interim (attached hereto).

It is expected to conduct some laboratory work in the various field study areas. In order to prepare the way for an early start on such work the engineer should determine as soon as possible the local laboratory circumstances under which examination of samples collected in that area could be carried out, and advise the Cincinnati office so that personnel, or mobile laboratory, arrangements can be made. It may be possible in some areas to obtain both laboratory space and cooperation of local laboratory personnel in carrying out a modest amount of such work; in other cases it may be necessary, and feasible, to furnish a laboratory technician from Cincinnati, or to provide mobile laboratory service for a short period of time. So far as is now known the bulk of the examinations will be the solids determinations on sewage, sludge and soil, in connection with which the Cincinnati office should be advised whether the necessary equipment, such as an analytical balance, water bath, drying oven, muffle furnace, desiccator, Gooch crucibles and suction apparatus, are available at the local laboratory, and whether they could be used full time or part time under the particular circumstances of the laboratory. The availability of a 20° incubator and distillation apparatus should also be reported on for consideration of special work in the area.

Instructions on field sampling procedures will be provided field engineers as soon as a number of factors involved can be worked out at the Cincinnati Laboratory. Pending receipt of such instructions it is suggested, in the event that local laboratory facilities and assistance are available at this time, that a sample taken at the outlet end of the quiescent tank, and another taken from the tank outlet at peak solids overflow, during a flush discharge, be examined for the following: volatile and fixed total solids, volatile and fixed suspended solids, settleable solids, turbidity, methylene blue stability, odor, pH and temperature. For purposes of uniformity of circumstance the flush discharge should be that produced by the draining of a bath tub upon which is superimposed a toilet flush and one faucet fixture fully open. The peak solids sample should be selected from a series of samples collected separately over the period of the flush discharge, the one selected being that which shows highest turbidity.

The engineer should, with the help of the local officials, make an early appraisal of the number, types and locations of the septic tank disposal systems in the area, and plan his

inspections so as to cover a number of installations of each type and size, preferably spread over the area, before the end of May, 1947. Special or routine investigations will possibly be carried on in the area, or in another area, beyond that time, but it is important, in view of the scheduled June 30, 1947 report on stage one and two items, that the bulk of the septic tank information in the area be at hand by the end of May. The memo on the local laboratory circumstances and the various kinds of tanks available for investigation in the area should be made to the Cincinnati office as soon as practicable, to assist in the coordination of work in various areas and the planning of special work.

Form reports on each installation investigated should be made in duplicate, one copy being mailed to the Cincinnati office as soon as completed, the other retained in the field file. Particular care should be taken to make every form report count, as the omission of key items will depreciate its value. A brief memo may be turned in to cover an inspection for which the regular report is not made.

To: Field Engineers
From: S. R. Weibel
Subject: Addition to report form instructions

1. In addition to the data required in Item 12 by the initial instructions, please use the following classification to show the type of tank.

2.	O - Round	T - Tile
	R - Rectangular	C - Concrete
	V - Vertical	B - Brick
	H - Horizontal	CB - Concrete block
	S - Steel	CMB - Concrete manhole block

Examples:

- OVS - round, vertical steel tank
- OOOVT - 3 compartment, round, vertical, tile tank
- RC - rectangular concrete
- OHC - round, horizontal concrete tank

U. S. PUBLIC HEALTH SERVICE
Environmental Health Center
Cincinnati 2, Ohio

INSTRUCTIONS - FORM, "SURVEY OF HOUSEHOLD SEPTIC TANK SYSTEMS"

This form has been prepared for use by U. S. Public Health Service personnel in recording field examination of household septic tank systems in connection with a cooperative study of a household sewage disposal systems being made by the U. S. Public Health Service for the Office of the Housing Expediter. The normal use of this form does not include extended observations at any particular installation. Extended examinations will be considered special assignments made through arrangement with the Cincinnati office.

Because of laboratory personnel circumstances, field engineers should arrange with householders to obtain permission to collect tank effluent samples when a chemist, by arrangement with the Cincinnati office, can be scheduled to the particular survey area laboratory for a limited period.

Individual survey reports should be forwarded to the Cincinnati office as soon after the inspection as possible, without waiting for effluent sampling results (to be reported on a laboratory form). Efforts should be made to complete the report on the form, briefing observations and comments to essentials necessary to a clear understanding. If expansion of any item is necessary it may be placed on an auxiliary sheet and attached to the form report.

- Item 1. Location - Provide name of occupant and address of property.
- Item 2. Informant(s) - Sources of information, other than investigator observations, used in preparing report.
- Item 3. Bedrooms - Insert the number of bedrooms.
- Item 4. Persons - The number of persons considered as residents of the dwelling.
- Item 5. Water Supply - Identify the system supplying water to the property. Investigator should procure a copy of a recent analysis from the company or municipality serving the area and attach to one of the inspection reports in the area.
- Item 6. Water use summer, winter - Report the average gallons per capita per day water consumption during summer and winter months, based on metered records and number of persons indicated under item 4.
- Item 7. Plumbing Units to septic tanks - list plumbing units tributary to septic tanks, such as water closets, bath tubs, lavatories, sinks, showers, laundries, tubs, washers, floor drains, or other units; (to other) - list and identify disposal of drainage from plumbing units not tributary to septic tank system.
- Item 8. State whether bulk of laundry is done at home (yes, no).
- Item 9. Drainage - List and indicate disposal of storm drainage and de-watering facilities (roof drains, sub-drains, etc.).
- Item 10. Garbage grinding - Indicate whether residence has a garbage grinder. (Yes, no).
- Item 11. Layout sketch - Sketch on reverse side of sheet the lot layout, showing dwelling, water lines, wells, drains, sewers, traps, septic tank system. Identify pipe kinds, sizes, joint materials, depth of cover. Indicate ground surface cover areas and, by

arrows, North, prevailing winds, surface slopes (estimated per cent). Give ground water depth during dry and rainy seasons, dimensions of lot, length of pipe lines, distances between sanitary units and, lot lines, dwelling and water supply structures. Indicate also water supply and sanitary structures on adjacent property within 20 feet of property under consideration.

Septic Tank

- Item 12. Type - Manufacturers name, type and number, or other design identification (Joint Committee or other federal, state, county, or municipal design identification).
- Item 13. Rating - Nominal rating in number of persons, together with total capacity below water line in gallons, as stated by manufacturer or other design agency.
- Item 14. Date Installed - Self explanatory. "By" - specify whether installed by manufacturer, plumber, occupant, or other.
- Item 15. Instructions - What instructions were provided for the guidance of the householder concerning operation and maintenance of the system, particularly with regards to cleaning.
- Item 16. Sketch - Sketch on reverse side, plan elevation and section, and provide sufficient dimensions and notations to completely describe tank and appertainences. Include inlet and outlet details, baffling, vents, covers, man-holes, drains, siphons, etc. Identify back fill; show ground level, scum and sludge circumstances as found, together with thickness measurements.
- Item 17. Date Cleaned, etc. - Insert date when tank was last cleaned, by whom cleaned, and what circumstances prompted the cleaning of the tank.
- Item 18. Cost - The total and unit cost of last cleaning. Include any previous cost data under item 24.
- Item 19. Seed - What practice was followed in reseeded the tank, if any.
- Item 20. Scum Amount - Give the quantity of scum in cubic feet as calculated from measurements taken at time of inspection. Three spaces are provided to enable distribution of scum volume where multiple compartment installations.
- Item 21. Sludge, Amount - Instruction similar to item 20.
- Item 22. Describe - Odor, appearance and consistency of scum and sludge; and any remarks on their distribution.
- Item 23. Structural State - Insert observations on physical condition of structural materials with respect to corrosion, etc. Tie in with age where possible.
- Item 24. Tank History - Give history of operation and maintenance concerning such factors as clogging, flooding, freezing, odors, deterioration, or other difficulties; also features which contribute to adequate operation and maintenance. Show synchronization with absorption field history where connection is apparent.
- Item 25. Sampling - Indicate whether effluent sample has been, or can be, taken, or other circumstances in this connection.

Absorption System

- Item 26. Layout Sketch, Profile, Sections - Sketch layout of absorption system, including distribution box, on reverse side of sheet, showing pipe lines, joint spacings, construction materials, location of vents, if any, clean outs, etc. Sketch profile showing grades, grade boards, if any; sketch sections at inspection or seepage test locations, showing trench dimensions, pipe, packing materials, backfill, outline of discolored area, sludge accumulation. Show also log of soil to 1 foot below trench bottom level, including well log if available. Spot any trench openings and percolation test locations on layout.
- Item 27. Date Installed - If system has been relaid, or otherwise differs from the original system, explain the development of the present system in item 34.
- Item 28. Operation - Indicate how absorption system is operated; whether lines are alternated, otherwise rested, etc.
- Item 29. Trench area - Give computed bottom area of trench in square feet.
- Item 30. Previous Soil and Percolation Test Data - Give data as available.
- Item 31. Soil Classification, Samples - Classify soils temporarily on basis of sand, silt and clay composition, as sand, silty-sand, clayey-sand; silt, sandy-silt, clayey-silt, clay, sandy-clay, silty-clay. Samples of each of the soils indicated in the soil log (item 26), together with trench bottom samples, should be shipped to the Cincinnati laboratory in tared mason jars provided for the purpose. If wet weight, or wet and dry weights, cannot be obtained in the field, seal jar by dipping top in paraffin after placing cap.
- Item 32. Physical Examination Field - State any significant observations on effluent distribution, sludge accumulation, odor, appearance of pipe, joints, soil, packing material, back-fill and surface cover, from examination of trench openings.
- Item 33. Percolation Tests - Make one (or more as circumstances may warrant), percolation test in the unaffected soil area at trench bottom level, using a foot square hole, saturating the sides and bottom, and observing the time in minutes required for 6 inches of water, poured into the wet hole, to seep completely away. Make also modified percolation tests in the unaffected soil area at trench bottom level, and in the bottom of the absorption trench itself, using the 10 inch diameter tube of galvanized iron to confine the water, pushed into the soil slightly to effect a seal. A sufficient number of modified percolation tests, possibly three, at selected locations in the trench should be made to permit an average percolation rate to be computed for the trench bottom. The number and distribution of trench tests for a particular system layout is left to the judgment of the field engineer. Tests should be numbered and spotted on layout sketch (item 26) and results reported individually here (item 33) in average minutes per inch.
- Item 34. History - Give significant history of field synchronizing with tank history or other pertinent circumstances where evident.

Filter, Filter Trench

- Item 35. Layout Sketch, Sections - Sketch filter or filter trench on reverse side of sheet showing dimensions, distribution and underdrainage, appurtenances, and filtering medium. Indicate or identify destination of effluent.

Item 36. Date Installed - Self explanatory.

Item 37. Sand, or other Fine Medium, Samples - Send a sample of fine medium to the Cincinnati laboratory. Record any pertinent information in this connection here.

Item 38. Sampling - (Special cases) - Indicate installations for which permission to later collect composite samples for filter performance can be obtained.

Item 39. History - Give significant detail of operation and maintenance.

Item 40. Remarks - Insert here any additional observations, miscellaneous items, local costs of tank, absorption field, filter, etc., installations, the cost of relocated absorption field lines, etc.

U. S. PUBLIC HEALTH SERVICE
ENVIRONMENTAL HEALTH CENTER
Cincinnati 2, Ohio

Budget Bureau No. 68-4704
Approval Expires 12-31-47

SURVEY OF HOUSEHOLD SEPTIC TANK SYSTEMS

REF. NO. _____ REPORT BY _____ DATE _____

1. Location _____
2. Informant(s) _____

3. Bedrooms _____ 4. Persons _____ 5. Water Supply _____

6. Water use summer _____, winter _____ g.p.c.d. 7. Plumbing units to septic tank _____
_____ to other _____

8. Laundering _____ 9. Drainage _____ 10. Garbage Grinding 11. Layout Sketch. (Back of Sheet) _____

SEPTIC TANK

12. Type _____ 13. Rating _____ persons _____ gallons _____ 14. Date _____ installed _____, By _____ 15. Instructions _____
_____ 16. Sketch (on back). 17. Date Cleaned _____, By whom _____ Reason _____ 18. Cost _____ 19. Seed _____

20. Scum, Amt _____ cu. ft. 21. Sludge, Amt _____ cu. ft. 22. Describe _____

23. Structural State _____
24. Tank History _____

25. Sampling _____

ABSORPTION SYSTEM

26. Layout sketch profile sections (on back). 27. Date installed _____, orig. system? _____ (if not, explain under 34) 28. Operation _____

29. Trench area _____ sq. ft. 30. Prev. soil and perc. test data _____

31. Soil Classif. samples _____

32. Phys. exam. field _____

33. Perc. tests _____

34. History _____

FILTER, FILTER TRENCH

35. Layout sketch, sections (on back). 36. Date installed _____ 37. Sand, or other fine medium, samples _____

38. Sampling (special cases) _____
39. History _____

40. Remarks _____

June 11, 1947

Study of Household Sewage Disposal Systems

To: Field Engineers
From: S. R. Weibel
Subject: Field Investigations - Percolation Tests

Preliminary investigations into the percolation tests at the Cincinnati Laboratory indicate the desirability of obtaining a larger volume of observations and a wider spread of soils than are possible to obtain here.

Until such time as the study has progressed to the point where percolation test procedures may be set up for the routine examination of absorption field systems, it is requested that field engineers, until further notified, make and report their percolation tests in accordance with the instructions given below.

Where investigation shows that ground water table is very close to, or above, trench bottom level, percolation tests need not be made. However, where sewage standing in an absorption trench is due to local clogging or actual lack of permeability of the soil, and not as the result of a general high water table circumstance in the vicinity, the submerged tests, using the 10-inch tube, should be made.

A. Number, Type and Location of Tests

One (or more as circumstances may warrant), in unaffected soil area using a 12-inch square hole, dug to trench bottom level.

One, in unaffected soil area, near the 12-inch square hole location above mentioned, using the 10-inch diameter tube, in a hole dug also to trench bottom level.

Three (more or less), at selected locations in the bottom of the absorption system trench, using the 10-inch tube. The number and distribution of these are left to the judgment of the field engineer, the aim being to determine the average percolation rate of the trench bottom. All tests made in this connection however should be reported individually.

B. Preparation of Test Hole

Before saturating test hole, place 2 inches of washed coarse sand, or pea gravel in bottom of test hole, or after the 10-inch cylinder is in place.

Saturate hole to at least 8 inches above top of sand or gravel.

In connection with making tests by means of the tube, it was found at Cincinnati that a 2-inch penetration of the tube into the soil was necessary in some cases to effect a seal. In all cases care should be taken to secure an effective seal.

C. Test

Refill hole, bringing water level up to between 6 and 8 inches above top of sand level, or, where sewage is standing in the absorption trench, bring water level up to between 6 and 8 inches above the sewage level outside the tube.

D. Observation

The data sheet, Percolation Test Form, has been prepared for use in this connection, most of the items on which are self-explanatory.

Items above the tabular form, and the test observations in columns (1), (2) and (3) of the tabular form, should be made in the field. The remainder of the table is for use by the Cincinnati office. No computations or graphs are to be prepared in the field.

All vertical measurements should be referred to a common origin, such as a reference board across the top of the unconfined hole or the top of the tube. This includes distance to the bottom of hole, top of sand, ground surface and water levels.

Water level observations should be made at approximately 2 minute intervals for the first 10 minutes, and at approximately 10 minute intervals thereafter, to complete a total run of 1 hour, or the time it takes to observe the total 6 inch subsidence, whichever is the shorter. In a very permeable soil, it would be advisable to take observations more frequently, and in a heavy soil to extend the total time of observations, if time permits. Time entries in column (1) should be "clock time."

When the test is made in an absorption trench in which sewage is standing, record the levels both inside and outside the tube for each observation (columns (2) and (3) respectively).

E. Samples

A soil sample at test level should be taken for every percolation test made, including those in absorption trenches. These should be shipped to the Cincinnati office for analysis.

Percolation Test Form

Insp. ref. no. _____

Date _____

Observer _____

Computer _____ Date _____

Location of property _____

Location of hole _____

10" Rd. confined _____ 12" Sq. unconfined _____ Air temp. _____ °C Water temp. _____ °C Soil sample-jar no. _____

Vertical height in inches, from reference point (_____): to ground surface, _____
(identify)

to bottom hole _____, to bottom of tube _____, to top sand or gravel _____, to starting water level inside tube _____,
outside tube _____.

Remarks _____

Time of day Hr.: Min.	Height ref. to W. L. (inside)-in.	Height ref. to W. L. (outside)-in.	Δt	$\Sigma \Delta t$	d	Δd	$\Sigma \Delta d$	A	A'	$\Delta 'd$	$\Sigma \Delta 'd$

U. S. PUBLIC HEALTH SERVICE
ENVIRONMENTAL HEALTH CENTER
Cincinnati 2, OHIO

LABORATORY RESULTS
(Survey of Household Septic Tank Systems)

Ref. No. (Survey Report) _____ Sample No. _____ Date Collected _____

Location (installation) _____

Time collected _____ (hour); by _____

Sampling Point, method and circumstances of collection _____

Chemical analysis by _____ Laboratory _____ Date _____

Oxygen Demand at 20°C

pH _____ Temp. _____ °C Method _____

Date	Days	Percent	Burette Reading		Normality	ml.	Dissolv. Oxygen	Oxygen Dem.
			Initial	Final				

Dissolved Oxygen Temp _____ °C

Date	Burette Reading		Normality	Milliliter	Dissolved Oxygen
	Initial	Final			

Oxygen Consumed

Method _____ Miles/ Sample _____

Milliliter Dichromate	Normality	Ml. Fer. Amm. Sulfate			Normality	Dichromate consumed-ml	Oxygen Consumed
		Initial	Final	Dif			

Total Solids

Milliliter Sample _____ Before Ignition Ignition at _____ °C _____ min. Calculated
_____ (ash) _____ volatile solids

Weight dish and solids		
Weight dish (initial)		
Weight solids		
Ppm.		

Suspended Solids

Milliliter sample _____

Weight xble + Solids		
Weight xble (initial)		
Weight of solids		
Ppm.		

Alkalinity

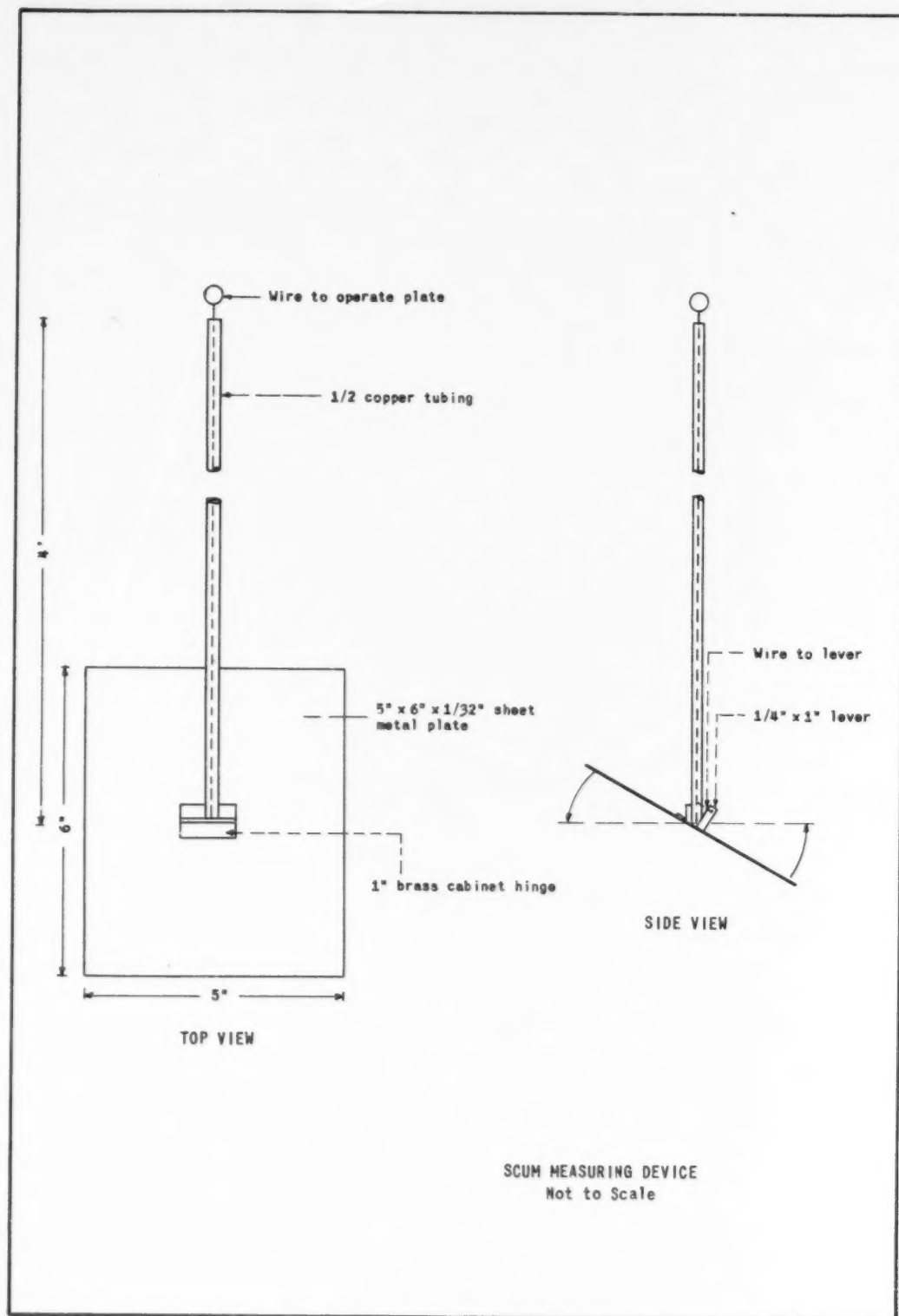
pH _____ Method _____

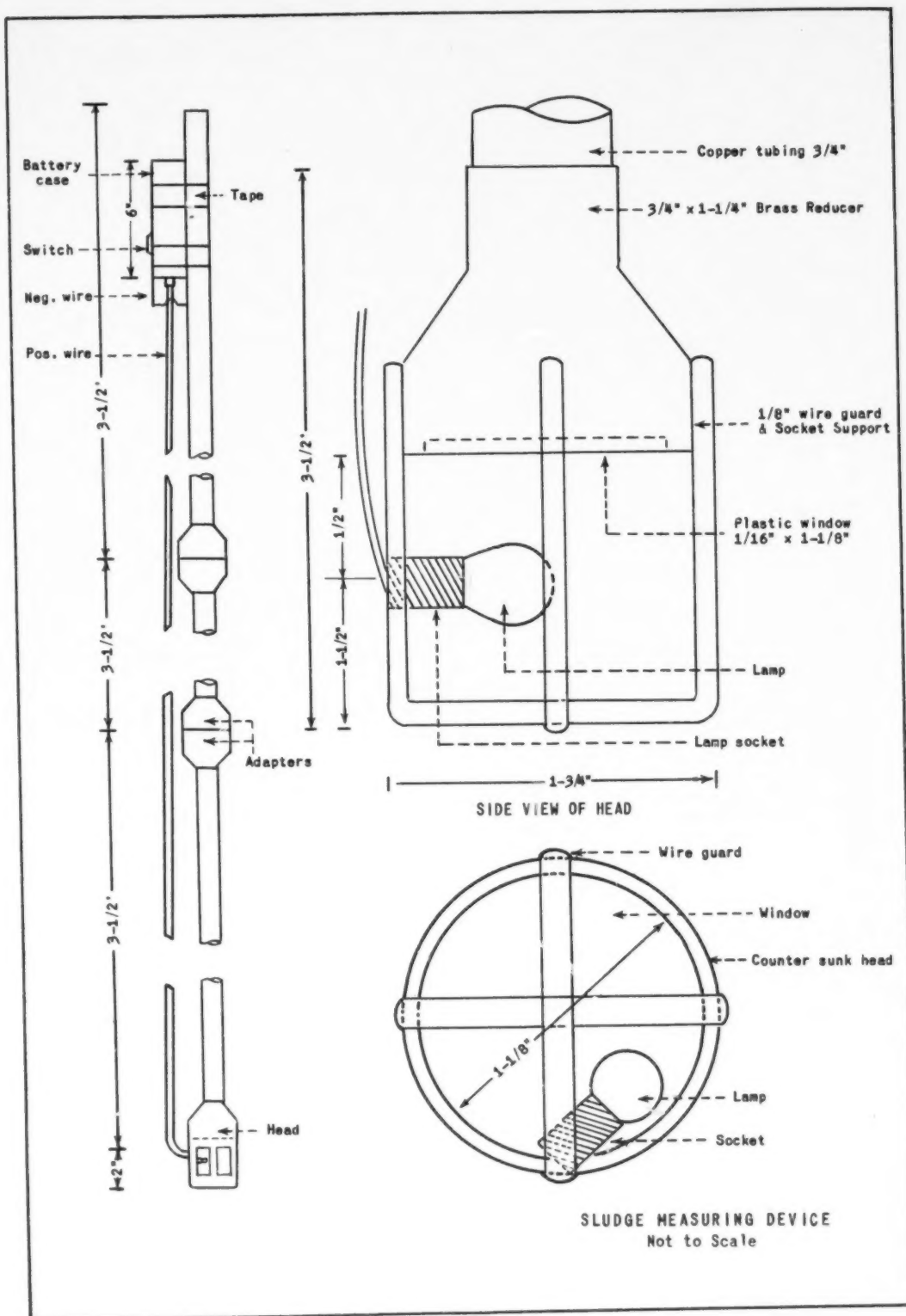
Milliliter sample	Indicator	Burette Reading		Solution	Milli- liters	ppm (as CaCO_3)
		Initial	Final			

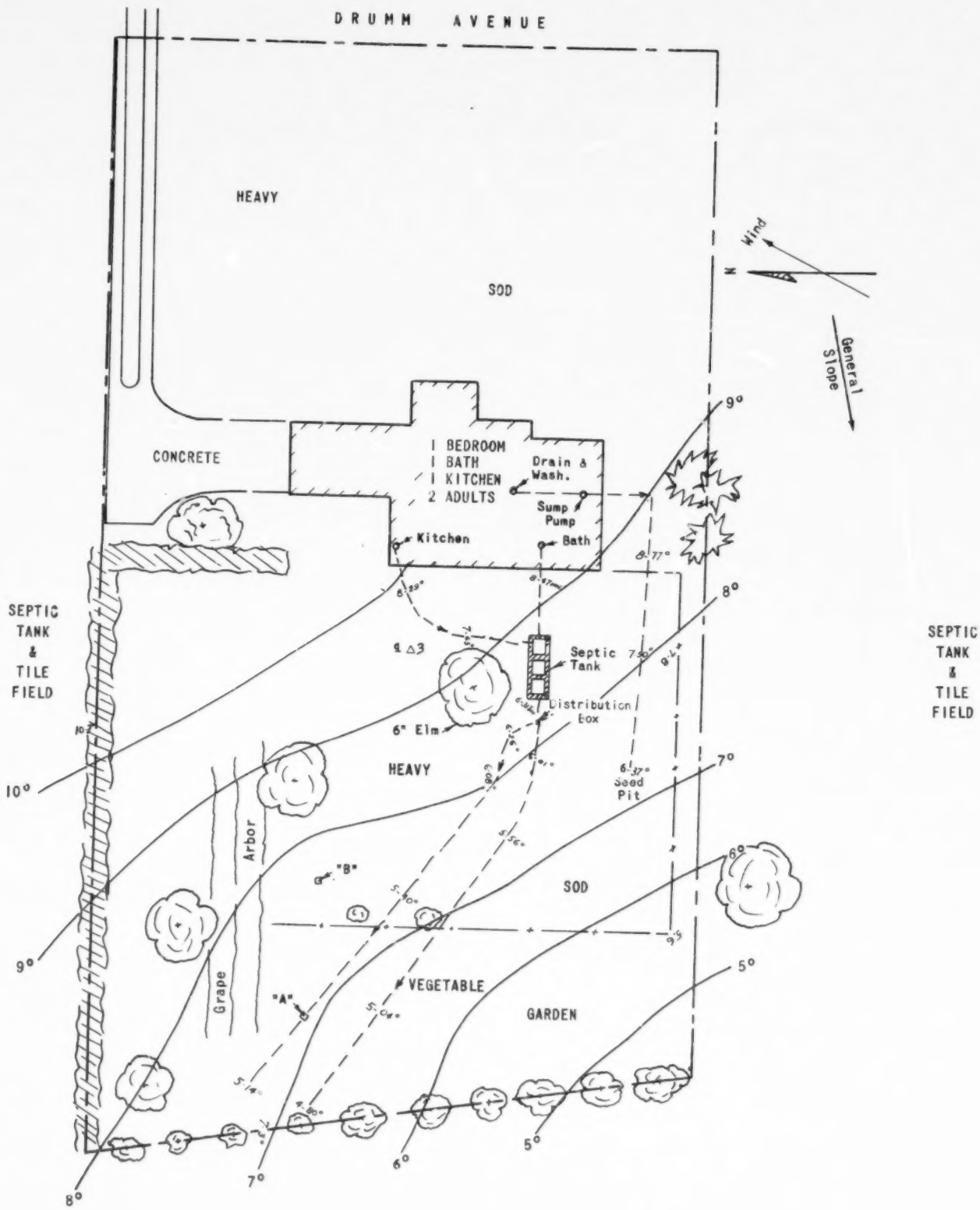
Settleable solids

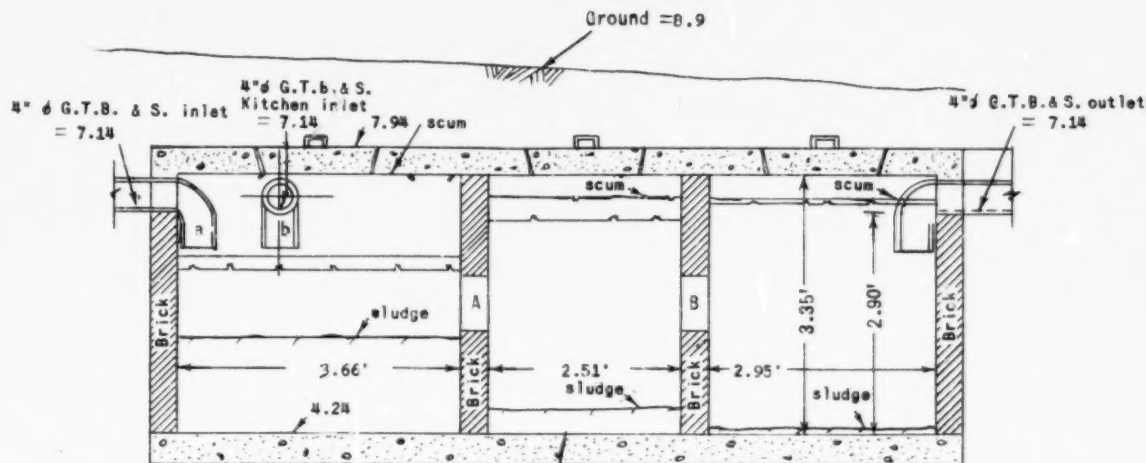
Milliliter sample	Time	Settleable Solids-ml

Remarks



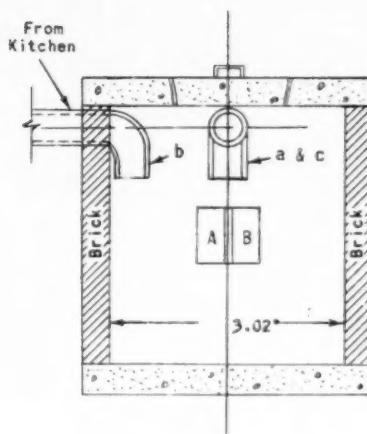




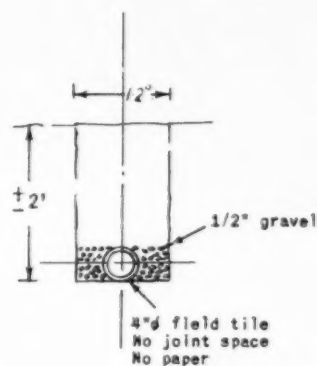


SEPTIC TANK SIDE VIEW & SECTION
1" = 2' - 0"

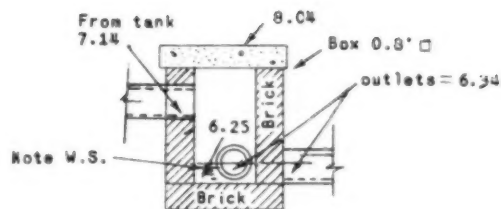
SEPTIC
TANK
&
TILE
FIELD



END VIEW & SECTION
1" = 2' - 0"



TILE FIELD SECTION
AT
PERC. TEST "A"
1" = 2' - 0"



DISTRIBUTION BOX
1" = 2' - 0"

II-36

REF. NO. 4-36 REPORT BY REITER DATE 7-10-47

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APPENDIX E

SURVEY OF INFORMATION ON THE FREEZING ASPECTS
OF HOUSEHOLD SEWAGE DISPOSAL SYSTEMS

FEDERAL SECURITY AGENCY
U. S. PUBLIC HEALTH SERVICE
SANITARY ENGINEERING DIVISION

(To plumbers in northern areas)

Dear Sir:

This Station in cooperation with the National Housing Agency is conducting a study of septic tank systems for home sewage disposal in connection with the Veterans' Emergency Housing Program. As part of this study we are attempting to determine operating conditions as they exist in the colder climates.

Your name has been referred to us by a plumbing supply wholesaler in your locality, as one being able to furnish information concerning your experience in installing, servicing, and repairing such systems.

Specifically, we desire information on the following points:

1. What is the usual practice in installations with which you are familiar in your locality, as to the depth of the house sewer, the tank and tile field?
2. Do you know of any tile fields 18" to 24" below the ground surface?
3. Do these shallow systems freeze if in constant use?
4. What part of the system freezes first; the sewer, the tank, or the tile field?
5. Are any special precautions taken, such as covering the tank and field with hay or manure, or other measures?
6. Are dosing siphons generally used?
7. Do you know of any cases where a shallow system installed in the Fall freezes the first Winter and operates satisfactorily after that? What about installations made in the Spring in this connection?
8. Are the lines of the absorption field vented to the ground surface? Have you found any difference in operation, with respect to freezing circumstances, between vented and unvented tile fields?

In addition to the above items, we would be glad to have your comments on any points not covered or unusual experiences you may have had with septic tank systems.

Please accept our sincere thanks for your consideration of this request, and we hope that we shall have your reply shortly.

For the Officer in Charge.

Very truly yours,

N.H.F.A.-U.S.P.N.S. Household Sewage Disposal Project

Tabulation of Questionnaire Response, Freezing Aspects - Solicitation Northern Plumbers

<u>No.</u>	<u>Location</u>	<u>(1)</u>	<u>(2)</u>	<u>(3)</u>	<u>(4)</u>	<u>(5)</u>	<u>(6)</u>	<u>(7)</u>	<u>(8)</u>	<u>Remarks</u>
1	Long Prairie, Minnesota	3 feet	No	--	--	--	No	No	No	Cover outlet, if to open ditch.
2	Hanley Falls, Minnesota	2-1/2 feet to 8 feet	No	No	--	No	No	Yes	Few ¹	Vents frost shut.
3	Cape Vincent, New York	--	Yes	No	--	--	--	--	--	
4	Evans Mills, New York	2 feet to 4 feet	Yes	No	Sewer ¹	Yes ²	No	No	No	¹ Freezes if faucets leak. ² Cover outlet, if to open ditch.
5	Watertown, New York	1-1/2 feet to 2 feet	Yes ¹	No	Sewer	No	No	No	--	124 inch cover is maximum.
6	Watertown, New York	1 foot to 1-1/2 feet	No	No	TF	Yes	No	Yes	No	
7	Virginia, Minnesota	3-1/2 feet to 4 feet	Yes	Yes ¹	TF	Yes ²	No	Yes	No	¹ If no snow cover. ² Cover system-8 inches to 10 inches manure.
8	Fargo, North Dakota	2 feet to 5 feet	Yes	No ¹	TF & Tank	Yes ²	No	Yes	Yes	¹ If in constant use and straw or manure cover is used. ² 23 feet-4 inches dirt banked over system.
9	Belfast, Maine	1 foot	No	No	TF	No	No	Yes ¹	No	¹ Only one instance.
10	Jamestown, North Dakota	6 feet	No	Yes	Sewer	No	No	Yes	No ¹	¹ Vented on larger installations, no difference between vented and unvented systems.
11	Duluth, Minnesota	3 feet	Yes	No	TF	Yes	No	No	No	
12	Theresa, New York	1-1/2 feet to 2 feet	Yes	No	None	No	No	Yes ¹	No	¹ Will not freeze.
13	Hibbing, Minnesota	3 feet to 4 feet	No	No	None	No	No	No	No	

No.	Location	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Remarks
14	Winona, Minnesota	4 feet	--	--	None	Yes ¹	--	--	--	¹ Bank dirt if impossible to get 4 feet cover.
15	Williston, North Dakota	5 feet to 8 feet	No	--	--	--	--	--	--	
16	Pierz, Minnesota	--	Yes	No	TF	No	No	Yes	No	
17	Barron, Wisconsin	1 foot to 3 feet	Yes	No	TF	No	No	No	Yes	
18	Conway, New Hampshire	1 1/2 foot to 1 foot	No	No	Sewer	No	No	No	No	Snow is good freezing protection.
19	Redwood, New York	6 feet	Yes	No	TF	Yes	No	No	Fe ²	TF freezes more readily when vented.
20	Duluth, Minnesota	3 feet to 4 feet	Yes	Yes	TF	Yes	No	No	No	Experience is limited.
21	Montpelier, Vermont	2 feet	--	--	None	Yes ¹	No	--	No	¹ Snow fall is heavy. Recommended.
22	Littleton, New Hampshire	--	Yes	No	Any	Yes ¹	No	No	No	¹ Cover tank when used only in summer.
23	Mattoon, Wisconsin	4 feet to 6 feet	Yes	No	TF	No	No	No	No	
24	Standish, Michigan	--	Yes	No	--	No	No	No	No	
25	Forestville, Wisconsin	2 feet	Yes	No	Sewer	Yes	No	No	No	
26	Bismarck, North Dakota	4 feet	Yes ¹	Yes ²	TF	--	No	--	--	¹ One instance, school. ² One instance, school.
27	Houghton Lake, Michigan	1 1/2 foot to 1 foot	Yes	No	TF & Tank	No	--	Yes	No	Keep seepage bed 6 inches to 12 inches below ground.
28	Montivideo, Minnesota	6 feet	No	--	--	--	No	No	No	
29	Craftsbury Common, Vermont	2 feet	Yes	No	--	No	--	No	No	

<u>No.</u>	<u>Location</u>	<u>(1)</u>	<u>(2)</u>	<u>(3)</u>	<u>(4)</u>	<u>(5)</u>	<u>(6)</u>	<u>(7)</u>	<u>(8)</u>	<u>Remarks</u>
30	Woodsville, New Hampshire	3 feet	No	--	None	No	No	--	No	
31	New Richmond, Wisconsin	3 feet to 8 feet	--	--	TF	No	No	Yes	--	
32	Superior, Wisconsin	2 feet	Yes	No ¹	TF	Yes	No	No	Few	¹ 1 foot new straw-better than manure.
33	Alexandria Bay, New York	2 feet	Yes	No	TF	Yes	--	No	Yes	¹ Good grade in TF is important.
34	Canby, Minnesota	3 feet	Yes	No	TF ¹	Yes	Yes	Yes	--	¹ At end of tile line.
35	Muskegon Heights, Michigan	2 feet to 3 feet	Yes	No	TF	No	No	No	No	
36	St. Johnsbury, Vermont	2 feet	Yes	No ¹	None	No	No	No	No	¹ If snow cover.
37	Clayton, New York	2 feet to 3 feet	Yes	No ¹	TF	No	No	Yes	No ²	¹ Occasionally first year. ² Vented TF's freeze quicker.
38	Stillwater, Minnesota	3 feet to 3-1/2 feet	--	--	--	--	--	--	--	V-shaped trough over tile-6 inches to 8 inches leaves or sawdust and all covered with heavy roofing paper.
39	St. Johnsbury, Vermont	2-1/2 feet	Yes	No	Sewer	--	--	--	--	
40	Austin, Minnesota	5 feet to 6 feet	No	1	1	Yes	No	No	No	¹ No direct statement.
41	Red Wing, Minnesota	1	No	--	--	2	No	No	No	¹ Uses seepage pit. ² Should be covered.
42	Red Wing, Minnesota	4 feet	No	--	TF	1	No	No.	No	¹ Should be protected. Freezing likely in clay or fine sand. Unlikely in gravel or fissured rock.
43	Alma, Michigan	1 foot to 1-3/4 feet	Yes	No	None	No	--	--	No	
44	Traverse City, Michigan	1-1/2 feet	Yes	No	TF	No	No ¹	No	No	¹ For 10 per cent of systems.

No.	Location	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Remarks
45	Clare, Michigan	3 feet to 4 feet	No	1	2	3	Yes	No	No	1Shallow system will freeze. 2Outlet of the field. 3Installed below frost level.
46	Springfield, Minnesota	1	No	--	Tank Outlet	Yes	No	No	No	1Use seepage pits.
47	Laconia, New Hampshire	3 feet to 4 feet	Yes	1	TF & Sewer	Yes ²	No	No	No	1No direct answer. 2For shallow installations.
48	Waseca, Minnesota	2-1/2 feet to 3-1/2 feet	--	--	--	Yes ¹	No	Yes	No	1Some are not protected.
49	Greenleaf, Wisconsin	2-1/2 feet to 4-1/2 feet	No	--	TF	Yes	No	Yes	No	
50	Plymouth, New Hampshire	2 feet	Yes	No	TF ¹	Yes ²	No	No	No	1If under plowed area. 2For exposed tanks.
51	Albert Lea, Minnesota	3 feet to 8 feet	Yes ¹	--	--	--	No	--	--	1Serve summer homes.
52	Grafton, North Dakota	4 feet	--	--	--	--	--	--	No	
53	Gibbon, Minnesota	1-1/2 feet to 2 feet	Yes	No	--	--	--	--	--	
54	Kenyon, Minnesota	1	No	No	TF	Yes	No	No	No	1Below frost.
55	Saginaw, Michigan	1-1/2 feet to 2 feet	Yes	No	None	No	1	No	2	1Sometimes. 2Sometimes vented. No difference in operation.
56	Lewiston, Michigan	1/2 foot to 3 feet	Yes	No	TF or Sewer	No	No	No	1	1Some vented. No difference in operation.
57	Newport, Minnesota	2 feet to 6 feet	No	--	Sewer	Yes	No	No	Yes	
58	Fish Creek, Wisconsin	1-1/2 feet to 2-1/2 feet	Yes	No	TF	No	No	No	No ¹	1Vented fields freeze.

<u>No.</u>	<u>Location</u>	<u>(1)</u>	<u>(2)</u>	<u>(3)</u>	<u>(4)</u>	<u>(5)</u>	<u>(6)</u>	<u>(7)</u>	<u>(8)</u>	<u>Remarks</u>
59	Wheaton, Minnesota	2-1/2 feet to 3 feet	--	--	TF	Yes ¹	Yes	No	No	¹ Sometimes.
60	Alma, Michigan	18 inches	Yes	No	None	No	Yes	No	No	
61	Monroe, New Hampshire	18 inches to 24 inches	Yes	No	None	No	No	No	No	
62	Sebewaing, Michigan	18 inches to 24 inches	Yes	Se1- dom ¹	TF	Yes ²	No	yes	No	¹ Usually in spring. ² Occasionally.